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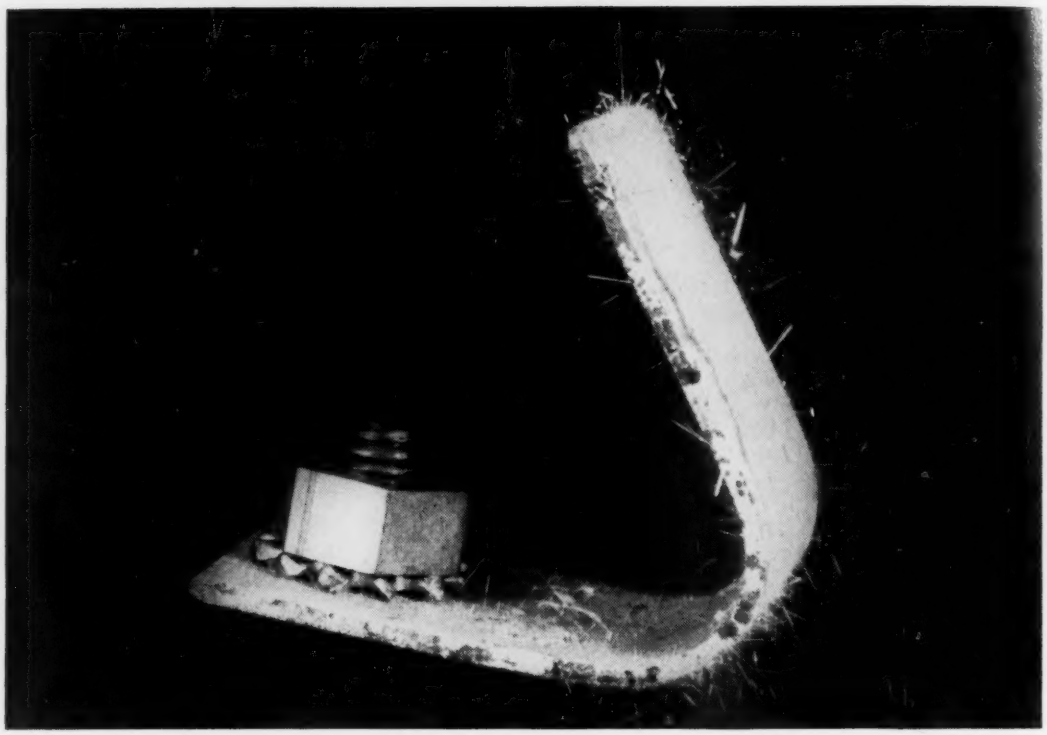


Whiskers on tin-plated steel, enlarged 6 times. Immense yield strength of metals in whisker form was discovered by Bell scientists.

The clue of the metal whiskers

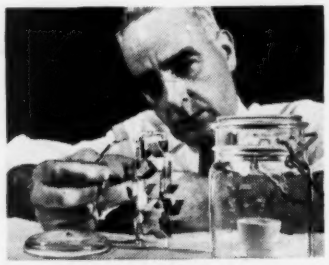
The habit of close observation at Bell Laboratories often turns "tremendous trifles" into important scientific progress. Such a case occurred when unexplained short circuits in wave filters seemed to be associated with a small zinc-plated mounting bracket.

Close scrutiny disclosed a whiskery growth on the zinc plating. Similar whiskers of tin were found growing on tin-plated equipment. Studies showed the whiskers to be tiny single crystals of metal.

Suspecting that these unusual crystals might be of essentially perfect structure, alert Laboratories scientists saw an opportunity at last to test an important metallurgical theory.

The scientists studied the whiskers, grew larger ones, and showed that the crystals had enormously high yield strength as predicted by the theory for perfect crystals – a strength far greater than for the same metal in any other known form. This clue has opened new frontiers in the study of what makes metals strong or weak, and has excited metallurgists all over the world.

Thus, another new advance comes from the Bell Telephone Laboratories practice of scrutinizing *everything* that means better telephone service.



Through the study of thousands of specially cultivated whiskers, Bell scientists seek to prevent treacherous growths in telephone equipment.

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THE SCIENTIFIC MONTHLY

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Cover: Chambered Nautilus

[Courtesy A. M. Winchester, Stetson University, De Land, Florida, see page 299]

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Science and Technology

(From the month's news releases: publication here does not constitute endorsement.)

Plastic Coating Material

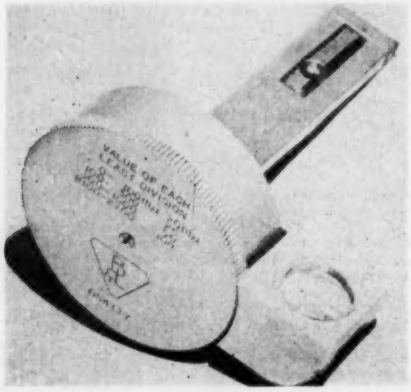
Finished tools and work parts can be given a protective coating by dipping them into a plastic material known as Dip Seal. The material, which must be heated to a temperature of 350° to 360°F, provides a coating strong enough to resist the effects of rough handling and to prevent corrosion during storage. The film, which sets up in 35 sec, is about 0.06 in. thick and has a flash point of 435°F. (Dip Seal Plastics, Inc., Dept. SM, Rockford, Ill.)

Infrared Detectors

Sensitive elements of newly designed infrared detectors are 10-μ-thick rectangular flakes of thermistor material. Dimensions of each element can be varied from 0.1 to 10.0 mm. A shielded compensating element minimizes the effects of ambient temperature changes. Housings are hermetically sealed and do not require a vacuum. (Barnes Engineering Co., Dept. SM, 30 Commerce Rd., Stamford, Conn.)

Accessory Slot Compensator

Bausch and Lomb has introduced an accessory slot compensator, which can be attached to most standard microscopes, that is intended to aid in the identification of minerals and chemicals. The accessory slot compensator is used to measure birefringence; readings are then obtained from determination charts. Determinations correct to ± 2 percent without calibration are read directly in millimicrons from a scale engraved on a rotatable drum; computations and conversion tables are not needed. The instrument performs with greatest efficiency when light of wavelength 5890 A is used; an interference filter is available for use with tungsten illuminators. The instrument can be used to measure retardations from 0 to 2700 mμ; scale divisions are engraved on the side of the instrument. (Bausch and Lomb Optical Co., Dept. SM, Rochester, N.Y.)



Stereophonic Home Music System

A new stereophonic music system for home use has been produced by Ampex Corp. Utilizing a phonograph that plays two separately recorded sound tracks from a single tape, music originating from the right and left sections of an orchestra is reproduced separately through two amplifier-loudspeaker systems. The result is a sense of direction and depth not previously achieved in home music systems. The phonograph can be purchased without audio amplifiers or speakers for use with existing high fidelity equipment, but an additional amplifier and speaker must be furnished if stereophonic sound is to be reproduced. (Ampex Corporation, Dept. SM, 934 Charter St., Redwood City, Calif.)

Automatic Titrator

Employing the second derivative of the voltage/volume function both to determine the end-point of a titration and to actuate a burette valve at that point, a new automatic titrator represents the successful instrumentation of H. V. Malmstadt's method for potentiometric titration [*Anal. Chem.* **26**, 1348 (1954)]. It is reported that the new automatic procedure can be applied to all common types of oxidation, reduction, acid-base, precipitation, and complexiметric titrations. The new instrument consists fundamentally of a mixing and delivery unit with associated supports and an electronic control circuit based on that originally described by Malmstadt. Neither preselection of voltage nor predetermination of cutoff point is required. The potential difference between the electrodes in the titration cell is amplified, differentiated, and filtered to produce a signal of sufficient amplitude to actuate the burette valve. The instrument maintains delivery at full rate until the cutoff point is reached. It is equipped with a recorder outlet by means of which second derivatives may be recorded. (E. H. Sargent and Co., Dept. SM, 4647 W. Foster Ave., Chicago 30, Ill.)

Laboratory Hotplates

Three models of fast-response laboratory heaters that employ open-wire heating elements are intended to provide rapid and precise control of boil-up rates in aniline point determinations and benzol and turpentine distillations. A double radiation shield, one part made of stainless steel and the other of an aluminum-asbestos combination, insures that maximum heat reaches the flask and also prevents the blistering of bench tops. A "flip-over" ceramic top is beveled to accommodate large or small flasks. The heaters can be used in any Flexaframe set-up by the use of integral clamps which are provided. All three models are cased in stainless steel. (Fisher Scientific Co., Dept. SM, 717 Forbes St., Pittsburgh 19, Pa.)

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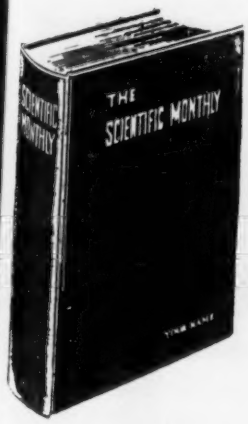

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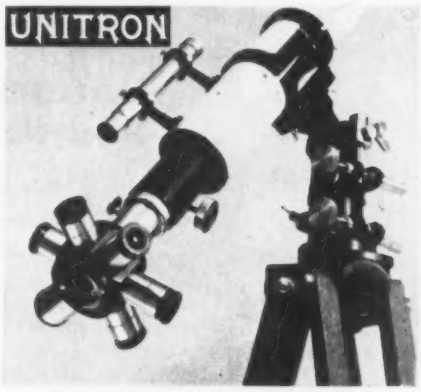

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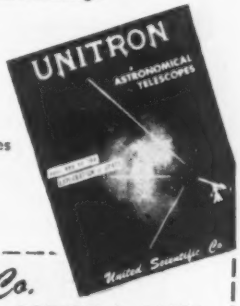

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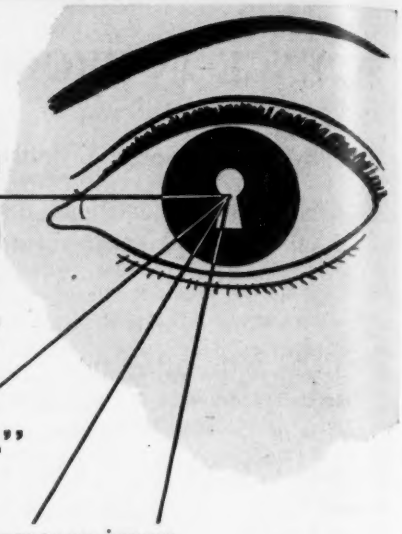

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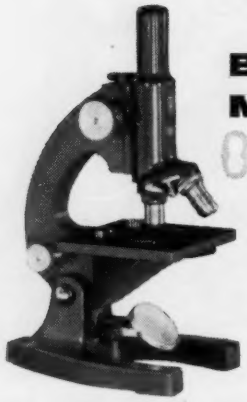

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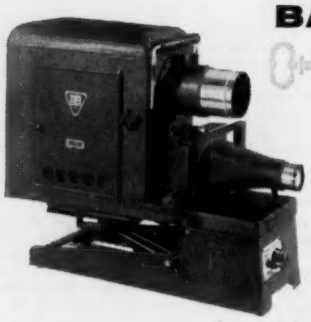

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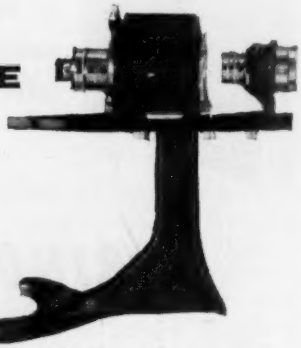

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DECEMBER 1955

Effects of Nuclear Weapons Testing

GORDON M. DUNNING

Dr. Dunning is a health physicist with the Division of Biology and Medicine, U.S. Atomic Energy Commission, Washington, D.C. His primary duties are concerned with biological effects of radiation, especially as related to nuclear weapons tests, and he has participated in all of these tests since joining the commission in July 1951. He received his education at Syracuse University and still maintains interest in his major field at the university, that of education of scientists.

DURING the past decade the United States has conducted a program of nuclear weapons development and testing. The release of energy equivalent to thousands and millions of tons of TNT, together with the production of large quantities of radioactive materials must be inherently accompanied by some degree of risk. Since the continuation of our nuclear testing program is mandatory to the defense of our country, the problem then becomes one of *defining* these risks and of *evaluating* them in the light of what is best for the peoples of the free world.

The information given here provides answers toward three basic questions raised concerning the testing of nuclear weapons: (i) What are the problems and possible risks associated with nuclear weapons testing? (ii) What are the data concerning effects from past tests and what might they be if the tests are continued? (iii) What do these data mean—how serious are the possible risks?

Blast and Thermal

Blast. The blast effects are limited to areas near the site of detonation. Partial damage to structures may extend for about 2 miles for a nominal-sized bomb (equivalent in energy to 20,000 tons of TNT) (*1*) and for 10 miles or more for high-yield weapons. However, reflection of blast waves from layers of the atmosphere may focus the blast wave producing greater pressures than are usually expected at that point (*2*). These reflected waves have caused some structural damage outside of the Nevada Test Site. Total claims paid to date for such damage amount to $44,342.18. No person has been injured directly or indirectly from these test blasts. Thus, there is some slight risk of minor structural damage such as broken windows in areas around the Nevada Test Site, but the blast pressures outside the site will have no direct detrimental effect on human beings and animals.

Thermal. Significant amounts of heat radiation may be received out to 2 miles from a nominal bomb (*1*) and about 20 miles for a high-yield weapon. Also, at the time of a nuclear detonation the light produced from a nominal bomb may temporarily blind a person if he looks directly at it, even from a distance of 30 to 40 miles. The brilliance of a nominal bomb rivals that of 100 suns when viewed at a distance of 6 miles (*1*). The simple act of turning the head away from the line of detonation can give adequate protection. For these reasons, motorists near the Nevada Test Site are warned prior to each detonation. In the past, four military personnel participating in the Nevada tests have received eye injury—three superficial that have completely healed, and one serious. No one has been injured off the test site.

Radiations

External exposure. At the time of detonation the almost instantaneous gamma rays released will be of concern out to about a mile for a nominal bomb (*1*) and out to a few miles for high-yield weapons. However, significant amounts of radioactive fallout may occur at more than 300 miles downwind from high-yield weapons. This material emits gamma rays similar to the instantaneous ones but with less quantum energy.

About 25 roentgens of gamma radiation, delivered in a short time (about a day or less) over the whole body, are required to produce minor and transitory changes in the blood; about 100 roentgens are required for some persons to show radiation sickness; about 450 roentgens may be lethal to half of the exposed persons (*3*). (A roentgen is a unit for measuring the amount of radiation, or dose, that has been received. For example, a normal x-ray will deliver about 1/10 roentgen or more to the chest; about 10 roentgens are received in a lifetime from cosmic rays and from naturally occurring radioactivity in the air, water and soil, *4*).

The highest radiation exposure to any individual in the United States outside the Nevada Test Site has been about 7 roentgens (about 12 people) and for any community about 4 roentgens (*5*). These dosages are below the amount needed to produce any detectable effect and are far below the amount required to result in radiation sickness.

Following the 1 March 1954 thermonuclear detonation at the Pacific Proving Ground, an unexpected shift of the winds caused a heavy fallout over some of the Marshall Islands. The highest radiation exposure to the inhabitants of these islands was about 175 roentgens. Most of these people experienced radiation sickness, but there were no deaths. It was reported by the Japanese that some fishermen aboard a vessel near the Pacific Proving Ground on the same date received a higher exposure than this. They further reported that one of these fishermen died on 23 September 1954 from severe hepatitis. (Hepatitis is a condition not directly attributable to radiation.)

Fallout material also emits beta rays that travel at most a few meters in air and are of principal concern when highly active fallout material remains in contact with the skin for relatively long periods of time. This may result in skin damage that would appear like a burn and may ulcerate if the radiation exposure has been large enough (*6, 7*).

Beta burns occurred on the skin of the Marshallese exposed to the fallout described in the preceding paragraph. Also, some cattle in 1945 and 1952 and some horses in 1953 experienced skin burns caused by the beta radiation from the fallout material being in contact with their skin following continental tests. All were within 20 miles of ground zero. Cattle from the 1945 exposure have been under observation at Oak Ridge. There have been no observable changes in the animals, except skin damage and loss of hair in spots that regrew but was gray in color. Their offspring have been normal in all respects.

These experiences have shown the need for larger warning areas when high-yield weapons are to be detonated. These are now established during operational periods; and with the continuing improvements in weather prediction, there is essentially no risk of hazardous amounts of fallout outside the control areas in the Pacific and continental United States.

Internal exposure (short term). Radioactive iodine present in fallout material may find its way into the body through ingestion or inhalation and will concentrate in the thyroid gland. There are several forms of radioiodine all similar in their radiation effect on the tissues but differing in half-life (the time required for the material to lose one-half of its radioactivity.) The half-life of the longest one of biological concern is only 8 days, however, so that the problem is one of short-term effects.

Because of their eating habits, grazing animals ingest materials over a relatively large area, which means that significantly larger amounts of radioactive iodine reach the thyroid. This gland is composed of tissue that is relatively insensitive to radiation. Experimental studies with sheep, for example, show that about 16,000 roentgens are required to produce even minimal changes in the cell structure and about 50,000 roentgens are required to produce definite cell damage and hypothyroidism (*8*).

The highest amount of radioactive iodine found in any animal due to fallout was in some sheep grazing near the Nevada Test Site during the spring of 1953. The estimated radiation dose to their thyroids was about 2000 roentgens (*9*). Owing to the more widespread distribution of fallout from the Pacific tests in the spring of 1954, radioactive iodine was found in the thyroids of cattle and sheep in various parts of the United States (*10*). The highest total radiation dose to the thyroid from this series was estimated to be about 40 roentgens. The peak thyroid measurements in animals during the 1955 test series were about 5/1000 roentgen per day (*9*).

Radioactive iodine in the thyroid of human beings resulting from intake of fallout material has been measured. The highest radiation exposure measured was in individuals near the Nevada Test Site in the spring of 1955, but there is some un-

certainty in the readings, owing to general contamination of the environment. However, if *all* the observed radiation is ascribed to radioactive iodine in the thyroid, the exposure amounted to a peak value of a few thousandths of a roentgen per day (*9*). The peak values for other human measurements in the United States for tests both in Nevada and in the Pacific have been generally one-tenth or less of this level.

These data indicate that the highest measured radiation dose to the thyroids of animals has been below the level that might produce harmful effects and that the highest measured radiation exposure to the thyroid of human beings has been far below that needed to produce any detectable effects.

Internal exposure (long term). One of the biologically important elements in fallout is strontium-90. If it is taken into the body, it is selectively deposited in the bones and continues to irradiate the surrounding cells for long periods of time, since it has a half-life of about 27.7 years. The deposition of relatively large amounts of strontium-90 in the bone would be expected eventually to produce bone tumors (*11*).

Owing to its relatively long half-life the amount of strontium-90 will accumulate in the environment if more is continually added. Assuming a constant rate of yearly addition and no loss through weathering, an equilibrium condition would be approached after 150 years—a state in which the rate of addition is equal to the rate of loss through radiological decay. About one-half of this equilibrium amount would be reached in 28 years. The equilibrium amount would be about 40 times the annual addition.

At the present time the average contamination of strontium-90 in the United States is about 15/100,000 microcurie per square foot. (A microcurie is a unit for measuring the radioactivity of a material. By definition, a curie is 3.7×10^{10} disintegrations per second; a microcurie is one-millionth of a curie.) This is about 1/240 of that of the soil's normal radium content (*12*) and 1/1300 of the amount (*9*) estimated to result eventually in the body's accumulating a maximum permissible body burden of strontium-90—a value considered safe.

If it is assumed that future nuclear tests would result in an *annual* fallout equal to the *highest* amount experienced heretofore in any one year, then the projected average for the United States after a period of more than 150 years might approach 13/10,000 microcurie per square foot (*9*). This is about 1/27 of the amount of radium that is usually present and 1/150 of the amount estimated to result eventually in the body's accumulating a maximum permissible body burden of strontium-90—a value considered safe. These possible trends will be continually checked by the Atomic Energy Commission's extensive monitoring program now in operation.

Neutrons (particles) that are released from a nuclear detonation react with a nitrogen atom in the air to form radioactive carbon, called carbon-14, which has a long half-life of about 5600 years. This radioactive carbon enters into the biosphere (the environment of living things) alongside normal carbon and thus finds its way into all living tissues and irradiates the surrounding cells. Since carbon is found in all living matter, the effects are similar to those when the whole body is irradiated by an external source.

Because of its long half-life the amount of carbon-14 in the world would accumulate until it reached an equilibrium state, a condition in which the rate of production is equal to its rate of loss by radioactive decay. Assuming a constant rate of production through yearly nuclear tests, an equilibrium condition might be approached after 30,000 years. One-half of the equilibrium value would be reached in 5600 years.

A nominal-sized bomb produces about 1/43 pound of neutrons (*1*). If it is assumed that each neutron will react with a nitrogen atom to produce carbon-14, then the total amount of this element produced would be about 1/3 pound. It has been suggested that a large thermonuclear weapon might produce as much as 140 pounds of carbon-14 (*13*). Accepting the foregoing estimates, if several large thermonuclear detonations occurred every year for 30,000 years, the near equilibrium amount of carbon-14 thus created in the world would be about 20 times greater than the amount now present.

There are about 180,000 pounds of carbon-14 maintained currently in nature in an equilibrium state, owing to natural production by neutrons (created by cosmic rays) reacting with nitrogen of the air (*14*). However, this amount contributes only about 1 percent to the total natural radiation dose received by the body (total natural radiation is about 3/1000 roentgen per week) (*15*). Thus, the equilibrium amount of carbon-14 (approached in 30,000 years) might increase the normal radiation dose to the body by 20 percent of the present value (*9*). The conclusion must be made that this effect is inconsequential.

Air, water, and fish. Air and water usually contain more than one naturally occurring radioactive substance (radon, thoron, radium, potassium, and so forth) (*16*). Inhalation of these radioactive materials present in the air results in a radiation dose of 3/100 to 8/100 roentgen per week being delivered to the lungs. The radioactive content in water

supplies varies greatly, but some has been found in essentially all sources. Rain will be radioactive, owing to the natural radioactive materials in the air. Not only is radioactivity found in air and water, but the amounts vary widely from place to place and time to time.

After the detonation of a nuclear device, some of the radioactive particles are small enough to remain in the air for long periods of time and thus to be carried by the prevailing winds over large areas. These particles may be inhaled, and also they may find their way into water and food supplies and thus be swallowed. A certain fraction of radioactive elements taken into the body are absorbed from the lungs and intestinal tract and deposited in various organs of the body. They are eliminated from the body—some rapidly, some very slowly—and as long as they remain in the body they irradiate the surrounding cells. The problem of inhalation and ingestion of radioactive materials fundamentally is no different from that of living in an environment of external radiation; hence, the problem is to determine what would be the radiation exposure, or dose, to the living cells of the body. The values that have been recommended by various expert groups for the maximum permissible concentration of radioactive materials in air and water are based on this consideration (*17*).

The highest activity observed in air anywhere in the United States (outside the control area in Nevada) has been about 1.3 microcuries per cubic meter of air averaged over the 24-hour period that the activity was present (*18*). The estimated radiation dose to the lungs resulting from this activity was about the same as would be expected from breathing air containing normal amounts of radioactive substances for a period of less than a month (*9*). The highest activity found in water in the United States has been about 1/7000 microcurie per 1/1000 liter (about 1/1000 quart) at 3 days after the detonation (*19*). This is about 1/36 of the maximum permissible amount—a quantity considered safe—even if the water had been stored and used as the sole source of supply for a lifetime (*12*).

Radioactive materials have been found in plankton and algae in higher concentrations than in the surrounding water. When fish eat these marine organisms, a small fraction of this radioactivity is retained within the fish. Fish containing greater than maximum permissible amounts of radioactivity (based on the assumption that they will be used as a principal source of food) have been found at the test atolls of Bikini and Eniwetok and in the nearby areas of heaviest fallout. Since it is the total amount of ingested radioactive materials (of known isotopic content) that is important, a limited quantity of fish containing above-maximum permissible concentrations might be eaten safely, but their continual consumption would be undesirable.

The presence of such radioactivity in tuna fish was reported by the Japanese following the Pacific test in the spring of 1954. The highest activity reported by the Japanese was found on the skin of the fish aboard the vessel *Fukuryu Maru* (*Fortunate Dragon*). This was the ship that received the direct fallout on the day of detonation, 1 March 1954, and the source of the radioactivity measured on the fish was principally the direct surface contamination as the fish lay aboard the vessel. The quantitative levels of activity found on these fish are unknown, but thereafter the highest activity was 1300 counts per minute measured by a Geiger counter, with shield open, held close to the surface of the fish. This latter activity is considered safe for unlimited consumption, by American permissible standards.

Genetics. There are five relevant points concerning radiation and genetics that may be enumerated.

1) Radiation can cause irreversible inheritable changes (called gene mutations) in the germ cells. Most of these mutations are considered harmful.

2) The number of mutations produced is independent of the rate of radiation exposure; that is, it is the total exposure to a given kind of radiation that is the important factor.

3) Radiations have not produced any kinds of mutations not already known and occurring normally. Thus, the possible effects of irradiation from nuclear detonations rightfully may be compared with those produced by natural causes.

4) If the mutation that occurs is of the "dominant" type, then the effect appears in the first generation. It is believed, however, that by far the largest number of mutations that do occur are of the "recessive" type that may be carried generation after generation without expression until it is matched by a similar mutant gene in the opposite sex—an occurrence of very low probability in a general population such as ours that is out-breeding (owing to taboos against marriage of close relatives). Thus, the presence of a mutant gene very rarely means a "defective" individual in the sense of detectable defects.

5) It has been estimated that natural causes (of which radiation from normal sources accounts for only 10 to 20 percent) (*20*) may produce on an average two additional mutations among every five individuals. Since we receive mutations from both parents, we may have on an average four "new" mutations in every five individuals, in addition to the very numerous "old" mutations inherited from

earlier generations (*21*). An estimate has been made by some that about 80,000 mutations may be present among the populace in the United States living 100 years from now owing to radiation exposure from all nuclear tests to date.

The average radiation exposure to people in the United States from all nuclear detonations to date has been about 1/10 roentgen (*9*). (This is the result of external radiation. Additional exposure of the gonads to any radioactive fallout taken into the body would be insignificant.) This is in addition to the approximately 7 roentgens that may be expected from natural sources over a reproductive lifetime—that is, an increase of 1/70 of the normal amount of radiation. If 80,000 mutations will be present in the population of the United States 100 years from now as a result of radiation exposure from all nuclear tests, then by the same calculations about 120 million (1500 times as many) additional mutations may be produced by natural causes during the same 100 years, assuming no increase in population over the 1955 census (*9*).

If it is assumed that future nuclear tests would result in an *annual* fallout equal to the *highest* amount experienced heretofore in any one year, then the average radiation exposure to people in the United States would be about 1/7 of that from natural causes and might increase the normal rate of mutations by 1.4 to 2.8 percent. If it is assumed that an average of two additional mutations are produced by natural causes among every five individuals, the new mutation rate might be 2.03 to 2.06 per five persons (*9*).

It is generally held that an increase in mutation rate is undesirable. These data and estimates give some perspective concerning the *degree* of risk involved.

Weather

There has been speculation on the part of some regarding the possible relationship between test nuclear detonations and the weather. Some of the effects suggested have been: (i) the particles of dust being thrown up by the detonation acting in a manner similar to silver iodide crystals used in cloud seeding to initiate precipitation; (ii) the change in the electric properties of the atmosphere owing to ionization produced by the radioactive particles; (iii) the reduction of direct solar energy received on earth owing to the dust thrown into the air by the detonation; (iv) the increase in number of tornadoes; and (v) the occurrence of drouth in the southwestern United States.

It is true that, following large nuclear detonations, minor weather changes, such as local cloud formation, sometimes with local precipitation, have been noted in the Pacific where the moisture conditions in the atmosphere were most favorable for this effect. However, experiments conducted by Air Force Cambridge Research Center on nucleating (cloud seeding) properties of Nevada dust and ionizing properties of radioactive fallout and studies made by the U.S. Weather Bureau on possible effects of nuclear detonations on electric properties of the air, solar radiation, tornadoes, and precipitation show the following (*22*).

1) Nevada dust has very poor nucleating properties; that is, ineffective as a cloud-seeding agent.

2) The amount of ionization produced by radioactive material is insignificant in affecting general atmospheric conditions.

3) Whereas, even relatively minor volcanoes may put enough dust into the atmosphere to decrease measurably the amount of direct solar radiation at the observation point established, no such decrease has been observed from any nuclear detonation.

4) Much of the increase in tornado reports during the past 5 years can be traced directly to the improved methods of reporting tornadoes that normally occur.

5) The present drouth in New Mexico began before the nuclear tests were started in Nevada. Similar drouths are on record for the 1930's and for earlier dates.

Thus the data and their evaluation to date present no evidence that nuclear detonations affect the weather, except as noted here for large detonations in the Pacific.

Nitric Acid Formation

At the time of a nuclear detonation, a minute fraction of the energy released causes nitrogen and oxygen of the air to combine, producing nitrogen dioxide, which in turn becomes nitric acid by uniting with water vapor. This acid may be brought to the earth by rainfall. The amount of nitrogen dioxide that persists following a nuclear detonation is less than what might be predicted on the basis of energy considerations alone, because the temperature of the fireball remains high for a relatively long period of time as compared with lightning, thus allowing some of the nitrogen and oxygen to dissociate (*1*).

It has been speculated by some that the amount of nitric acid formed from the detonation of a high-yield nuclear weapon equivalent to millions of tons of TNT would be great enough to produce an acidity of *p*H 5 in rainfall. (*p*H is the measure of acidity. A *p*H of 7 represents neutrality; the lower the number, the greater the acidity.) However, nitric oxides are added normally to the air by decomposition of organic matter in the earth and to a

much lesser degree by nitrogen and oxygen in the air combining under the influence of lightning (*23*). Thus, it has been found that the acidity (*p*H) of *normal* rain has average values of 4 to 5, which is more acid than that predicted by some for rain following the detonation of high-yield weapons.

Even if the assumption is made that nuclear bombs have a high degree of efficiency for nitric acid formation, then a nominal-sized bomb (20,000 tons of TNT equivalent) might produce 100 tons of nitric acid. It would require about four nominal-sized bombs detonated each day to equal the normal rate of addition of nitrogen dioxide to the air in Los Angeles county (*9, 24*). It would be necessary to detonate every day a nuclear weapon releasing the equivalent of 35 million tons of TNT to equal the normal rate of production of nitric acid in the world (*9*).

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The sages do not consider that making no mistakes is a blessing. They believe, rather, that the great virtue of man lies in his ability to correct his mistakes and continually to make a new man of himself.—WANG YANG-MING.

Ecological Experimentation with Animal Populations

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SUPPOSE *ecology* is given this definition: A domain of biology concerned with the environment, and environmental relationships, of plants and animals. The definition seems simple enough and, perhaps, clear enough. Yet, reflection will show that actually it encompasses a complexity of quite alarming proportions. In this article I touch briefly on certain of these matters, and, in the course of this, suggest one method of study (without denying validity to *other* methods) that, I believe, promises to advance the understanding of ecological phenomena.

Early biologists, often with superb competence, described the activity of an organism in its natural environment. Such matters as its reproductive behavior, its adjustment to prevailing conditions, and its method of locomotion claimed the attention of both professional and *aficionado*. This activity is known by the time-honored label "natural history." Although natural history has lost in popularity, it still retains for its practitioners a strong fascination, and it must continue to remain one of the prime sources of knowledge and insight for the modern ecologist. Much will be said in this article that seems alien, perhaps even antagonistic, to natural history, but this is illusory. In applying analytic methods to ecological problems one does not excommunicate natural history. Rather, one imposes upon it new dimensions of method and concept, thereby increasing his capacity to interpret events that are not otherwise interpretable through unaided observation.

The distinguishing characteristic of ecology is its ultimate preoccupation, not with the individual organism, but with the environmental relationships of groups. The group, or population, thus emerges as a natural entity. By virtue of interaction within its membership, by possession and transmission of a statistically distinctive heredity, and by adjustment to environmental stress, *new* phenomena arise—phenomena that are amenable to study and that, in themselves, constitute the conceptual core of modern ecological research. Like individuals, populations vary in complexity. In simpler perspective, they exist in space and in time as associations of single species. But nature is not a vacuum and, to survive, species must engage in some kind of intercourse with each other. This leads to increasingly intricate "levels" of biological organization with constant increase in intricacy of the emerging phenomena.

The upshot is that the ecologist studies (among other things) the quantitative behavior (census) of populations in conjunction with those factors that control this behavior. His attention may focus on a group constituted by only one species ("*intra*species") or, alternatively, on some association between species ("*inter*species"). The first, and intrinsically simpler aspect examines interplay among the group's membership in relation to the physical habitat. The question arises: How does the population accelerate, maintain, or decelerate its growth by virtue of its inherent capacity to reproduce, to die, or to disperse? The second aspect subsumes all relevant single-species phenomena but adds to these a new impact—an impact introduced when another species is found to live in reciprocity with the first. Let us pursue this abstractly. Imagine two different species and name them X and Y. X, say, is a plant and Y, say, is an animal that exploits the plant for food, space, and shelter. This assertion describes two biological interactions; that of X on Y and that of Y on X. Although the interactions are of negligible consequence if viewed in terms of *one* plant and *one* animal, the consequence for both participants becomes immediately evident when X and Y are viewed as populations. This shift in emphasis from the individual to the group leads to recognition of an ecological phenomenon —"struggle for existence" between a plant species

and a herbivorous animal species. Since the struggle can be perceived, it follows (in theory at least) that it can be studied and hence certain appropriate questions can be formulated. Some questions are *descriptive;* some are *analytic.* The former ask what is happening, while the latter search for a mechanism to explain the observations. A descriptive question might be: How rapidly does Y increase during a season of growth and what in turn is the effect of this on X? An analytic question might be: How does it come about that the numbers of Y reach a certain level beyond which they do not increase and how is X involved in such limitation?

In this example (lamentably simplified!) we introduced only that relationship established when the first population consists of plants and the second population consists of herbivorous animals. But there are at least four other common types of interspecies activity. It is convenient to designate these as "predator-prey interactions," "parasite-host interactions," "mutualism," and "competition." The formulation already applied to plants and animals is equally appropriate for predation and parasitization. All are grounded on the fact that the Y-population directly utilizes the X-population and both X and Y are thereby affected. Mutualism and competition, however, differ qualitatively from the others. In mutualism, X confers something beneficial for Y, and contrariwise. In competition, the view generally prevails that X and Y are not engaged in either frontal assault or in comity, but rather, are sharing and exploiting a resource that is available to both but limited in its supply. In a subsequent paragraph, I have more to say about competition because this is the phenomenon chosen for illustration.

II

Since ecology is an outdoor science, it is obvious that its component problems are studied in their natural setting. But it may not be equally obvious that certain problems lend themselves to laboratory exploration, and further, that some problems may even be attacked mathematically. These issues merit brief elaboration. The end-objective of "population ecology" is to understand those key processes that are responsible for numerical trends of populations. Owing to the inherent complexity of such processes, this is an objective far easier to state than to fulfill. Superimposed on this is a potent complication. The environment is characteristically variable and varying. The population responds to this and, in so doing, modifies its environment. These events are not under the control of the investigator although he may systematically record them in the field—a program leading to an impressive array of physical and biological information. But the information is likely to be difficult to analyze and even more difficult to generalize. Despite these handicaps, however, this approach must remain the principal one in study of population phenomena for the simple reason that it, of all others, *directly* comes to grips with occurrences in nature.

Suppose our interest lies in studying a "competition" presumed to arise when two species (X and Y, say) exploit a common source of food and space. Here, we view the phenomenon in its simplest terms by asking the following question: Do populations composed of X and Y differ significantly in their behavior from populations composed of X alone, and Y alone, if no other conditions of difference prevail?

It is immediately apparent that this question is infiltrated with assumptions that are quite unrealistic insofar as natural populations are concerned. Other competitor species, and/or species in different types of ecological association, would be present. The physical environment would be unstable—therefore not controlled. And it is unlikely that a situation would be easily found in which X and Y each could be observed in the absence of the other. Yet the fact remains that the question, though stylized, is worth asking and worth answering. Competition between species must be frequent throughout nature, often with appreciable genetic, ecological, and evolutionary consequences for the participants. Ideally, one would like to analyze the total problem in such a way that extraneous factors could be identified and those events caused purely by competition dissociated from those caused by dissimilar processes.

Difficulties of no mean proportion thus arise when populations are studied by direct measurement in the field. These have led to substitutes. Although they differ in conception, such substitutes can be characterized as "models" and share in common the following attributes: (i) they are presumed to represent the mechanics of at least a part of nature, but (ii) they do so in a guise purposely designed to enhance the interaction of certain factors, control other interactions, and eliminate still others. As suggested in an earlier paragraph, such models are either *mathematical* or *laboratory-experimental.* My concern lies only with the latter (*1*).

Let us take stock. We have claimed the phenomenon of interspecies competition for further illustration. We have given to competition a functional definition. And we have suggested that there are compelling reasons for studying such popula-

tion problems in the laboratory. However, before actual findings can be reported, we need to discuss briefly the organisms that were used, how they were used, how they were handled, and then specify the particular experimental design (2).

In 1928 R. N. Chapman (3) showed that a flour beetle possesses many attributes favorable for population research. The beetle, *Tribolium confusum*, lives entirely in, and on, flour and there passes through the developmental stages characteristic of all beetles (egg to larva to pupa to adult). Flour thus constitutes the total food supply and total space for this organism. When a pair of fecund adults is introduced into a bottle containing such food, a first generation appears in about 1 month at 29°C (84.2°F). If the flour is regularly renewed, the beetles multiply and maintain substantial cultures. In order to take a census, one sifts the infested medium in silk bolting-cloth sieves that retain all beetle stages but let the used flour pass through. The beetles so separated are readily counted. A weighed amount of flour, poured into a container, obviously assumes the form of that container; in this way the size and geometry of the beetles' "universe" is determined. Since flour acquires the temperature and humidity of the surrounding air, it follows that a climate can be imposed merely by keeping the experimental units in controlled cabinets. If certain precautions are observed, flour put into a group of bottles in weighed amounts at the start of an experiment is nutritionally homogeneous within each bottle, and also between bottles. These then, are the simple procedures used in research with *Tribolium*.

III

Our theoretical and methodological preparation is now sufficient to permit illustration by means of an actual laboratory study. Utilizing *Tribolium* as the material, and focusing on competition as the phenomenon, we combine the two elements in a specific experimental design. In planning such investigations, it is wise to recognize in advance the following four requirements that must be met: (i) that *two* distinct species are available, each of which uses the same resource; (ii) that each species is husbanded *alone* ("controls"), and both *together* ("experimental") in otherwise similar conditions of food, space, climate, and handling; (iii) that repeated censuses of all cultures are systematically taken for long enough intervals of time; and (iv) that statistically adequate replications of initially identical populations are started and maintained.

Let us expand this in more specific terms. The reader perhaps should be cautioned that throughout this extremely general article I have selected only certain items for discussion, to the ruthless exclusion of others—a procedure that is followed even more ruthlessly from here on. We have already introduced the beetle, *T. confusum*. Since another *Tribolium* (*T. castaneum*) is available, and is equally suitable, we have the biological equipment needed for studying *inter*species competition. A question that arises immediately—Shall only one climate of temperature and humidity be used, or more than one?—was answered by choosing three temperatures (34°, 29°, and 24°C), but one humidity (75 percent). These are physical conditions known from earlier work to favor multiplication and survival of both species. What is *not* known (and this is part of the design) is how the conditions are correlated both with numerical levels sustained by the populations and with the outcome of competition. Next, we define an experimental unit as a glass vial containing 8 grams of flour that receives initially four male and four female adult beetles. Every 30 days, again and again, all units are treated in the following way: The populated flour is sifted and discarded and the living stages, after counting and recording, are reintroduced into a new vial with 8 grams of fresh medium. This is continued systematically until the experiment is stopped—a span sometimes encompassing more than 4 years.

In the experiment there are three constant-temperature chambers all at the same humidity. The research is started by placing 70 vials (units) into each chamber. Of these 70, 20 vials contain only *T. confusum*; 20 contain only *T. castaneum*; and 30 contain a mixture of the two (2 male and 2 female *T. confusum*, and 2 male and 2 female *T. castaneum*). There is thus a total of 210 individual populations (3×70), distributed equally among three defined climates, and censused every 30 days. To be able to answer the question posed earlier, it is necessary to describe the behavior of each of the two species when alone (*intra*species competition) in order to interpret differences that emerge when the two are together (*inter*species competition). Hence, the single-species cultures are properly viewed as controls and the mixed-species cultures as experimentals. For convenience I have hereafter designated *T. confusum* as *X* and *T. castaneum* as *Y*.

Let us now review certain features of the actual research. Turning first to phenomena displayed by single-species controls, we are immediately faced with this important conclusion: *both* species persist successfully for many generations in all three conditions of temperature! In other words, nothing is imposed by the design that is inimical to sur-

vival. The point acquires a further validity on remembering that it is authenticated by the individual case histories of 120 replicates. We next inquire into matters of numbers—average beetle densities in the several experimental treatments. Such quantitative comparisons are of two kinds. Attention may focus on each of the two species as they respond to the stimulus of temperature. Or attention may focus on each of the three temperatures as these influence the behavior of one species when contrasted with the behavior of the other. The statistician would state these alternatives incisively as "between temperature-within species" and "between species-within temperature."

Comparisons of this sort are readily made by referring to Fig. 1. Here, the three temperatures appear as one axis, average population size as the other axis, and solid and open bars represent *X* and *Y*, respectively. Looking first at *X* (solid), we see that as the temperature becomes cooler the populations become smaller. Actually, all that can be positively asserted is that the most thriving cultures occur at 34°. The difference between 29° and 24°, though visually apparent, is not "significant" in the statistical sense—that is, it could often arise as an accident of chance. Species *Y* is also affected by temperature but in a way different from *X*. It maintains its greatest populations at the intermediate (29°) and lowest (24°) temperatures and its smallest populations at the highest (34°) temperature. If differences *between* species are now examined, we note that *X* and *Y* behave in a similar way at 34° (the slight advantage seen for *X* having no true validity); but at 29° and 24°, *Y* is markedly favored over *X*.

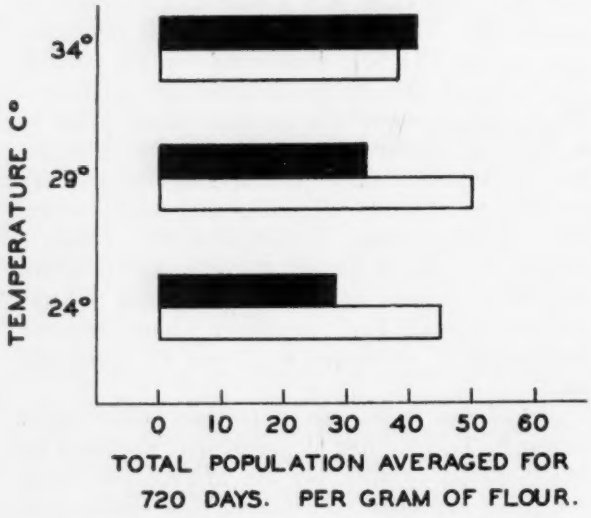

Fig. 1. Average population size sustained by single-species cultures of *Tribolium confusum* (black bars) and *T. castaneum* (open bars) at three constant temperatures.

In passing, as we now do, from the level of the single-species to the mixed-species population, we are obviously introduced to phenomena of much greater ecological complexity. These may be evaluated by asking two major questions of the data: Does the presumed competition between species indeed exist, and if so, what are its end results as indicated by the behavior of each of the competitor populations? Documentation is advanced in the five graphs that appear in Fig. 2.

These interspecies relations merit more attention. There is, again, a principal qualitative conclusion. One species *always* persists while the other species is *always* eliminated. This fact, clearly an expression of coassociation since it is not seen in controls, holds true irrespective of temperature and leads to the assertion that the existence of competition is proved. But the consequences of competition are multifarious and herein lie elements of novelty. Let us pursue this. We note from the chart two kinds of end results. In the first case (34°), one species (*X*) is eliminated by the other in all the vials. In the second case, the findings are "alternative;" *X* persists with certain frequency, as does *Y*. Thus at 29° the usual winner is *Y* but *X* survives in about 15 percent of the instances. At 24°, on the other hand, *X* is the usual winner but *Y* succeeds in approximately one trial in three. Earlier research (by others and myself) has reported species elimination in the face of stringent competition. However, to the best of my knowledge, a new point contributed here is the demonstration of alternatives even when the physical and nutritional environment is controlled throughout. This adds a new dimension to the phenomenon. It suggests that competition possesses an intrinsic plasticity—sometimes proceeding in one direction, sometimes in another, depending on the causal machinery. Such plasticity could have value for a species living in nature under variable (and less pampered) conditions. The machinery is not yet understood, but we are making progress in this direction.

As a last item, let us sketch the relationship between beetle numbers sustained in control populations and species-eliminations in experimental populations. Common sense argues that the species favored as a control would still be favored in competition. But, paradoxically, this is not necessarily so! Take events at 34°. Here, the environment is equally suitable for both species, as we have seen (Fig. 1). The logical prediction would be that, on coassociation, *X* would win in approximately one-half, and lose in approximately one-half, of the replicates. The prediction is not fulfilled; *Y* is the exclusive survivor. Competition confers an impact, over and above the control performance, that leads

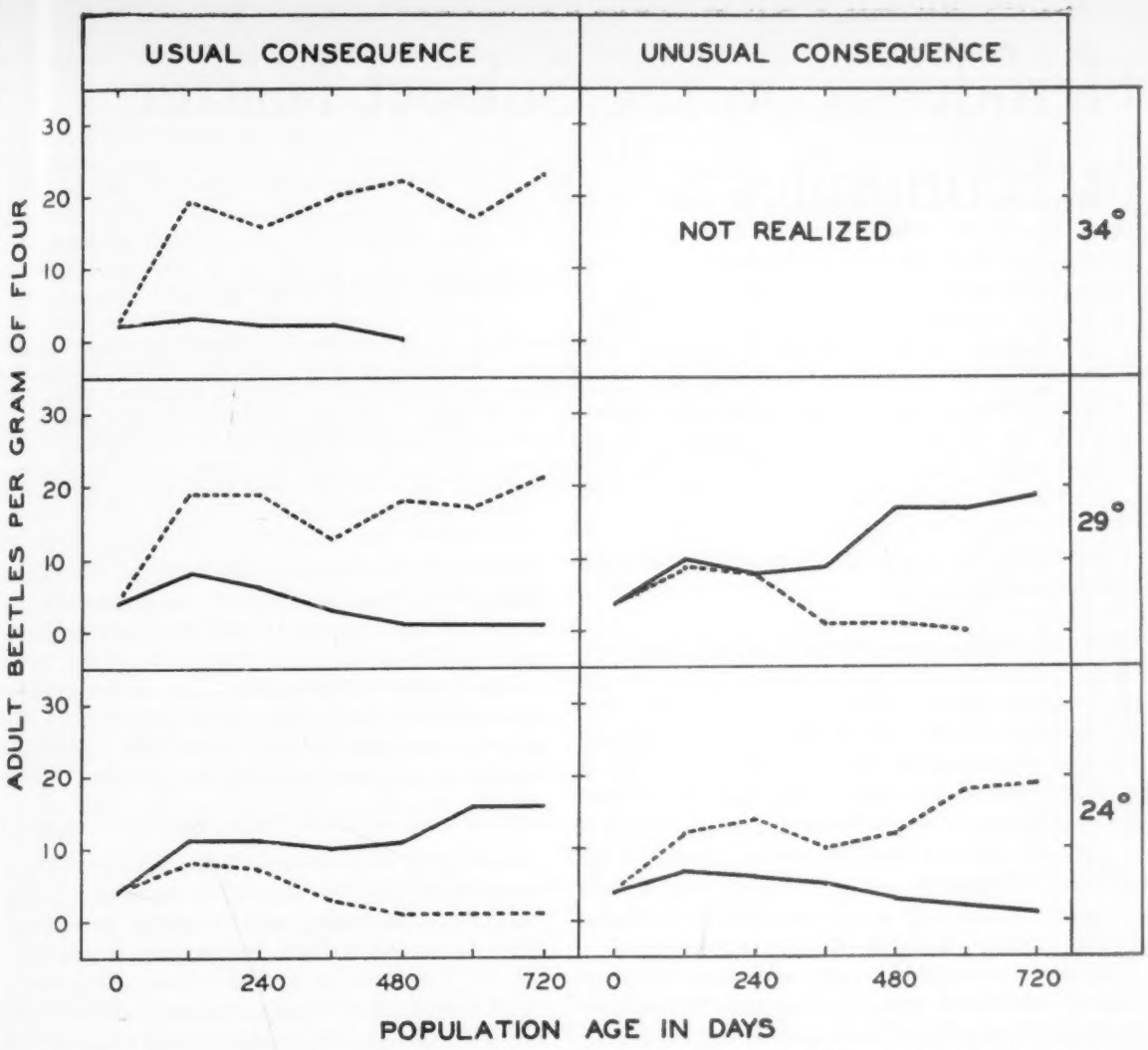

Fig. 2. Usual, and unusual, consequences of interspecies competition at three temperatures. Solid lines are *T. confusum*; broken lines are *T. castaneum*.

to invariable extinction of *X*. Examine events at 29° where consequences are alternative. In controls, *Y* displays a decided superiority and *usually* wins when the species are together. The control trend, however, can be contradicted and this actually happens in a small number of the instances. Finally, there is the extremely interesting situation in 24°. When living apart, *Y* maintains much greater average populations than *X*. Yet, when the two are competing, it is *X* that is the usual winner. Such findings complicate the phenomenon of interspecies competition no end but afford at the same time a certain fascination.

This concludes our demonstration of one approach to the study of ecology. No implication is made, or intended, that the observations are *directly* applicable to events in nature. However, it is maintained that there is merit in bringing a field problem into the laboratory under conditions sufficiently controlled to permit interpretation. To this biased practitioner at least, the procedure seems defensible on the grounds that it results not only in conceptual advance but also introduces certain rigors of thinking to a science that can make use of them.

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Herodotus on the Subject Matter of Economics

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The Greeks tell many tales without due investigation.—Herodotus, II, 45.

IT is customary to begin accounts of Greek economics with discussions of the views of the Socratic philosophers, although several of the pre-Socratic writers, especially Democritus (about 420 B.C.), did concern themselves with questions of this sort. Herodotus, first of the great Greek historians (about 484 to about 425 B.C.), touched upon many matters describable as economic in his *History* (*1*), most if not all of which was written between 448 and 429 B.C. It is with his treatment of these matters that this article is concerned.

His concern was principally with the customs of various non-Greek peoples: Lydians, Babylonians, Indians, Persians, Arabians, Massagetae, Egyptians, Libyans, Scythians, Thracians, and others who lived within, or in countries situated near, the Persian Empire, whose campaign against the Greeks had produced the war that was the main subject of *The History*. He referred also to peoples and lands lying near the periphery of the world as he knew it or had heard about it. He dealt with Greek economic practices only when describing Greek communities or contrasting them with other communities. There was opportunity also for him to fall back on economic principles to explain behavior that he reported.

Although Herodotus was not an Athenian, some of his opinions reflected Athenian views and frames of reference (*2*). He had no use for primitivism, saying that in the region above the Black Sea no nation had produced "a single person of any high repute" or could lay claim to wisdom (IV, 46). Extensive travel and recourse to a wide variety of sources underlay his work. But he lacked a systematic philosophy in terms of which to assess the underlying determinants of the series of events whereof he wrote, and, although he disbelieved many of the tales he repeated, he tended to give a personal or a religio-theological interpretation to much that took place (*2, 3, 4*).

I have collected his opinions under a number of convenient headings. After presenting these, I shall note what he neglected and appraise his significance for the development of economic thought.

Internal and External Trade; Handicraftsmanship

Herodotus was interested in the products of countries, articles that entered into commerce, ships and waterways, trade practices, and so on. Thus he refers to gold and silver production (for example, III, 57, 106, 114; V, 17; VII, 112); Arabian fat-tailed sheep, spices, frankincense, and so forth (III, 110–113); Indian cotton and muslin (III, 106; II, 95); amber, ebony, and tin (III, 114–115); silphium (IV, 169) and lotus (II, 92; IV, 177); the hemp of Scythia (IV, 74) and the linen of Egypt and Colchis (II, 105); olives, salted sturgeon, sweetmeats, palm-tree fruits, wild-bull horns, sesame and castor oil (I, 193; II, 94; IV, 53; V, 82; VII, 31, 126); pitch and bowls and cauldrons (IV, 61, 152, 195); bitumen and oil production (VI, 119); weights and measures (VI, 127); the carrying capacity of river boats and the navigability of various rivers (I, 194–195; II, 96; IV, 53). He remarked (IV, 24) on the number of interpreters required to carry on trade with peoples living beyond the Scythians. He described (IV, 196; also I, 1) the "dumb" or "silent" trade (*5*) carried on by the Carthaginians with a people living in Senegambia, a type of trade also encountered, according to Pliny (*6*), in Central Asia.

> There is a country in Libya, and a nation, beyond the Pillars of Hercules, which they are wont to visit, where they no sooner arrive but forthwith they unlade their wares, and, having disposed them after

an orderly fashion along the beach, leave them, and, returning aboard their ships, raise a great smoke. The natives, when they see the smoke, come down to the shore, and, laying out to view so much gold as they think the worth of the wares, withdraw to a distance. The Carthaginians upon this come ashore and look. If they think the gold enough, they take it and go their way; but if it does not seem to them sufficient, they go aboard ship once more and wait patiently. Then the others approach and add to their gold, till the Carthaginians are content. Neither party deals unfairly by the other: for they themselves never touch the gold till it comes up to the worth of their goods, nor do the natives ever carry off the goods till the gold is taken away.

He discussed (II, 178–179, also 135) the treaty port, Naucratis, entrepot of Greek-Egyptian trade, which was established on the Canopic branch of the Nile about 650 B.C. and flourished a century later under Amasis. He identified the Greek cities that shared in the cultural and commercial activities of this sole port of entry for trade on the Nile, but he did not reveal how much manufacturing the Greeks carried on there. He described how the Persians kept the way into Egypt through the Syrian Desert passable by storing water in earthen jars originally used to bring Greek and other wine into Egypt (III, 6–7).

Herodotus implied the incapacity of much of European and Asiatic Greece to supply all its food requirements. He noted the passing of corn ships from the corn-growing lands on the Black Sea (IV, 17) to Aegina and the Peloponnese (VIII, 147), the offer of Syracuse to supply corn on certain conditions (VII, 158), the dependence of Miletus on imported corn (I, 17–18), and the invulnerability of the Scythians (IV, 46, 127) to attempts to destroy their food supply, an invulnerability apparently not characteristic of Greek cities. He did not, however, refer to the politico-economic revolution (*7*, pp. 258–259; *8*, vol. 1, pp. 24–26, vol. 2, pp. 36–43; *9*, p. 41) initiated by Solon, who, in order to cope with Athens' insufficiency of breadstuffs and employment, forbade the export of produce other than oil, "turned the attention of the citizens to the arts of manufacture" and "gave dignity to all the trades" (*10*, XXII, XXIV), thereby facilitating the exchange of manufactures and agricultural specialities for imported foodstuffs. But, noting that it was desirable for a country (as well as an individual) to be self-sufficient, although impossible for one to be completely so, he made Solon observe (I, 32) to Croesus in an imaginary (*9*, pp. 184–187) interview:

> As there is no country which contains within it all that it needs, but each, while it possesses some things, lacks others, and the best country is that which contains the most.

Herodotus did not share the later Greek view that held craftsmanship, manual labor, and local trade in disesteem. This view developed after the Persian Wars, which magnified the importance of military activity and acquainted the Greeks with large-scale plunder and revenue. Perhaps he had this apparent change in Greek values in mind when he discussed the origin of Greek notions respecting trade and craftsmanship, although elsewhere (V, 6) he described as "remarkable" the Thracian glorification of idleness, war, and plunder, together with their depreciation of tillers of the soil, as "the most dishonorable." He mistakenly suggested (I, 94) that the Lydians ["proverbially a nation of shopkeepers" (*3*, vol. 1, pp. 102–103)], who "have very nearly the same customs as the Greeks," were, so far as he knew, "the first who sold goods by retail," thereby overlooking both the Babylonians and the Egyptians [whose "women attend the markets and trade, while the men sit at home at the loom" (II, 35)]. He described Corinth, noted also as a place where foreigners deposited sacred objects (I, 14, 50–51), as the Greek community most congenial to trade and craftsmanship, but he did not attribute this, or Corinth's prosperity [as did Strabo later (*11*)], to its being situated at what today we call a nodal or junction point (*12*). He was content to write (II, 167):

> Whether the Greeks borrowed from the Egyptians their notions about trade, like so many others, I cannot say for certain. I have remarked that the Thracians, the Scyths, the Persians, the Lydians, and almost all other barbarians, hold the citizens who practise trades, and their children, in less repute than the rest, while they esteem as noble those who keep aloof from handicrafts, and especially honour such as are given wholly to war. These ideas prevail throughout the whole of Greece, particularly among the Lacedaemonians. Corinth is the place where mechanics are least despised.

He contrasted the trade-favoring town life of the Greeks with the trade-despising feudal life of the rich Persians, whose luxurious mode of existence succeeded their conquest of Lydia (I, 71). He had Cyrus say to the Spartan herald (I, 153), "I have never yet been afraid of any men, who have set a place in the middle of their city, where they come together to cheat each other and forswear themselves"; and Herodotus observed, much as did Xenophon later (*13*), that

> Cyrus intended these words as a reproach against all the Greeks, because of their having marketplaces where they buy and sell, which is a custom unknown to the Persians, who never make purchases

in open marts, and indeed have not in their whole country a single market-place.

At the same time, however, Herodotus extolled the importance attached by the Greeks to nonmonetary honors; he made (VIII, 26) a Persian leader remark, when he heard that participants in the Olympic games contended for an olive wreath,

> Good heavens! Mardonius, what manner of men are these against whom thou hast brought us to fight?—men who contend with one another, not for money, but for honour!

Public Finance; Taxes

Herodotus commented a few times on the financing of "public" affairs, but he did not give a very complete picture of either Persian or Greek policy in this regard. He referred to the Greek practice of turning over one-tenth of windfall profits and war booty to a temple (I, 89; II, 135; III, 57; IV, 152; V, 77; VII, 132, 187; VIII, 122; IX, 81), and told (II, 180) how at least one-fourth of the 300-talent cost of rebuilding the temple at Delphi after its burning in 546 B.C. was raised by begging contributions in Greek cities and Egypt. He related (VII, 144) how Themistocles persuaded "the full-grown citizens" of Athens to forego each his share—10 drachmas—in the "large sum of money in their treasury" (originating in the produce of the silver mines at Laurium) and utilize this money to finance the building of 200 ships and thereby make Athens "a maritime power," overlooking the fact that Athens' 30,000 (V, 97; VIII, 65) citizens probably could not, on this basis, finance the building of more than 50 ships.

He also told of the Macedonians deriving a talent of silver a day from a mine (V, 17) and of the Siphnians being endowed with gold and silver mines whose yield was annually divided (III, 57). He reported (I, 64) that Pisistratus, supposing his power to rest upon mercenaries and a "full exchequer," got revenue from "native sources" and from "countries about the river Stryon," but he did not identify the former as including the then rich (VII, 144) silver mines at Laurium and a 10 (later 5) percent tax on land income (*14*, VI, 54).

Several instances of murderous exactions by Oriental despots, when on the march, were recorded (IV, 84; VII, 35, 39, 114). He stated that Darius required the satrapies (exclusive of Persia proper) to pay a fixed tribute, with some required also to furnish food and other things, whereas his immediate predecessors had relied upon their subjects' gifts (I, 192; III, 89–97; VI, 42). He stated also that each king, upon beginning his reign, remitted tribute due from the provinces, much as in Sparta the newly ascending monarch forgave all Spartans the debts they owed the king or the treasury (VI, 59). Land is represented as the primary source of tax revenue in Egypt (II, 109) and Persia (VI, 42).

Money and Monetary Theory

There is not much in Herodotus' works concerning monetary matters. He implied that money serves as a measure of value and a medium of exchange, but he said nothing about the practice or the morality of interest-taking. Only once is it implied—in an account (II, 136) of the Egyptian King Asychis' law that made a man's sepulchre pledge for his unpaid debts—that scarcity of money and depression of economic activity are associated.

> In the reign of this king, money being scarce and commercial dealings straitened, a law was passed that the borrower might pledge his father's body to raise the sum whereof he had need. A proviso was appended to this law, giving the lender authority over the entire sepulchre of the borrower, so that a man who took up money under this pledge, if he died without paying the debt, could not obtain burial either in his own ancestral tomb, or in any other, nor could he during his lifetime bury in his own tomb any member of his family.

Herodotus did not infer, however, that the annual collection of revenue [initiated by Darius (III, 89)], in the form of gold and silver worth 14,560 Euboic talents (about 3.67 million pre-1914 English pounds), together with its melting down, might exercise a depressive effect upon economic activity in Persia, since the king spent merely a part of this revenue, "when money is wanted," only coining "as much of this bullion as the occasion requires" (III, 95–96). He could not, therefore, forsee the stimulus to economic activity that would be given to economic progress (*15*, pp. 3 ff.) in the Mediterranean basin by Alexander's dispersal of the accumulated treasure of Persia, a fact that Plutarch also ignored (*16*, XXXVI, XXXIX–XL).

Herodotus remarks (I, 94) that the Lydians, "so far as we have any knowledge . . . were the first to introduce the use of gold and silver." He overlooked the fact that others preceded the Lydians in the coinage of silver and the use of electrum or minted coins, although the latter probably were the first systematically to mint coins of guaranteed weight and fineness (*3*, vol. 1, pp. 74, 102–103; *7*, pp. 311–312; *9*, pp. 90–111). He credits Darius with refining "gold to the last perfection of purity in order to have coins struck of it" and remarks that Persian satraps had the right to coin silver money (III, 89; IV, 166; VII, 28). He reports that the tribute required of the satrapies was expressed

in standard weights for gold and silver (III, 89), with a given weight of gold being worth 13 weights of silver.

He apparently did not recognize that Persia was on a bimetallic system, whereas gold-poor Greece was on a silver standard, nor did he anticipate that the value of a given weight of gold, expressed in terms of like weights of silver, would temporarily fall from 13 or 13.33 to 10 upon the dehoarding and demonetization of Persian gold by Alexander (*15, passim*; *7,* pp. 325–330). He employed the term *Hippobotae,* or *horse-keepers,* to describe a rich oligarchy (V, 77), a designation in keeping with the ancient practice of gaging an individual's wealth by his capacity to maintain horses. He referred (IV, 176) to a people, the comparative attractiveness of whose women was measured in terms of leather anklets.

Prices; Price Formation

Herodotus says virtually nothing on price determination. He wrote that the Phocaeans, having arrived at Chios in flight from besieged Phocaea, "made offers for the purchase of the islands called Oenussae, but the Chians refused to part with them, fearing lest the Phocaeans should establish a factory there, and exclude their merchants from the commerce of those seas" (I, 165). Earlier he noted (I, 163) that the Phocaeans, who used a long penteconter instead of "the round-built merchantship," were "the first of the Greeks who performed long voyages" and the first to trade with the Phoenician city, Tartessus, situated in Spain. Although he said nothing more of monopoly, he did recognize the impact of scarcity. He described (IV, 152) the case of a storm-driven Samian ship that reached Tartessus, "a trading town" and "in those days a virgin port, unfrequented by the merchants," with the result that "the Samians, in consequence, made by the return-voyage a profit [of 60 talents] greater than any Greeks before their day, excepting Sostratus, son of Laodamas, an Aeginetan, with whom no one else can compare." (The Aeginetans were known as the "pedlars of Greece Proper," just as the Lydians were known as "the Phoenicians of the land" *3,* vol. 1, p. 102). Herodotus said also that the Sigynnae were called pedlars (V, 9).

He referred to but one instance of fixed price, "the ransom of prisoners among the Peloponnesians . . . fixed at two minae the man" (VI, 79). He reckoned gold at "thirteeen times the worth of silver" (III, 95) and did not imply that the ratio might change. He stated that Cyrus, when on expedition, carried drinking water from the river Choaspes, "ready boiled for use" (I, 188), but he made no comment respecting the cost entailed. He remarked (IX, 80) how those ignorant of the value of objects sold them below their true value.

Population and Migration

Herodotus frequently made reference to demographic matters. He cited Solon as fixing "the limit of the life of man" at the Psalmist's threescore years and ten (I, 32), but elsewhere he reported the Persians as putting the maximum at 80 years (III, 22) and a Tartessian as living to 120 (I, 163). He gave values of 33.3 and 23 years for the length of a generation (II, 142; I, 7), which he defined, not as a modern demographer does, but as a unit of measure supposedly approximating the average length of a king's reign.

He commented on the Cretans having been decimated three times by war, famine, and pestilence (VII, 170–171); on the plague, disease, and dysentery that reduced Xerxes' troops as they retreated back home, changing water on the way (VIII, 115, 117); on the mortality sometimes associated with canal-building (II, 158) and other circumstances (III, 99; IV, 149); on Persian health-preserving practices (I, 138) and Egyptian contrivances against gnats (II, 95); on the institution of suttee (V, 5); on cannibalism (I, 216; III, 99; IV, 26); on ophthalmia (VII, 229; II, 111); on an alleged association of healthiness with stability of climate (II, 77), and of hardness of the skull with the exposure of the shaved head to the sun (III, 12).

He gave the gestation period as ten lunar months or less (VI, 63, 69). He reported that, because the pig was regarded as an unclean animal by the Egyptians, swineherds were "forced to intermarry among themselves" (II, 47) and related a tale about how the Scyths sought to mate with the Amazons in order "to obtain children from so notable a race" (IV, 111). For mid-sixth-century (B.C.) Egypt, "the number of inhabited cities" is given as "not less than twenty thousand" (II, 177). Assyria also is said to possess "a vast number of great cities," the dimensions of the most renowned of which, Babylon, he described (I, 178–186), albeit inaccurately.

Populationist sentiments appear several times in *The History.* Of the Persians he wrote (I, 136):

> Next to prowess in arms, it is regarded as the greatest proof of manly excellence, to be the father of many sons. Every year the king sends rich gifts to the man who can show the largest number: for they hold that number is strength.

How Darius took steps to prevent the Babylonian elite from becoming extinct is told (III, 159; see III, 149). The desire for children was used as a sanction against oath-breaking by the Pythoness of

Delphi when she declared, "But oath-keeping men leave behind them a flourishing offspring" (VI, 86), and as justifying the taking of a second wife when the first was sterile (V, 40). Leonidas is described as taking with him to Thermopylae only those with sons living, in order to insure the continuance of the family of each (VII, 205). In one place, however, Herodotus stated (I, 61) that Pisistratus, already a father, determined when he married a second time that "there should be no issue of the marriage" (*17*) but he did not make explicit the method employed.

Herodotus described various marriage customs (for example, I, 93, 196, 199, 216) but did not infer their effect upon the population, except to indicate that the Agathyrsi had wives in common in order to prevent hate and envy (IV, 104). He expressed no Malthusian sentiment, but he remarked that Darius, seeing "Asia abounding in men, and vast sums flowing into the treasury," determined to "exact vengeance from the Scyths" for an earlier invasion of Media (IV, 1).

Herodotus reported that a mythical breed of vipers would cover the earth and displace man if their growth were not held in check by an equally mythical contrivance of Providence (III, 108–109), but he did not extend his principle to the multiplication of men and animals except to suggest that the species most vulnerable to mortal attack tend also to be the most fecund and fruitful (III, 108). He stated (I, 66) respecting the Lacedaemonians that, "their soil being good and the population numerous, they sprang up rapidly to power, and became a flourishing people," but he did not indicate explicitly that the goodness of the soil had stimulated this population growth. He had Cambyses associate the increase of produce, children, and herds (III, 65), again without indicating the causal relationship if any. He attributed the continuing growth of the once scanty Hellenic race to "the voluntary entrance into its ranks of numerous tribes of barbarians" while the barbarian Pelasgi "never greatly multiplied" (I, 58), but he did not relate this growth to that of the food supply. He apparently did not appreciate the role of the polis in establishing order and security within regions and thereby making population growth possible, perhaps because he thought (I, 86, 207) that insecurity pervaded human affairs; and yet it is to the rise of the polis that Toynbee (*8*, vol. 2, pp. 96 ff.) traces the development of that population pressure which underlay subsequent Greek migratory and colonial movements.

Herodotus touched a number of times upon the migratory history of Greek and barbarian—"the greatest movement yet known in history," according to Thucydides (*14*, I, 1)—and furnished a partial history of the ethnography and Völkerwanderungen of the migrating peoples (see *3*, *4*, *18*). He did not explicitly associate these movements with population pressure, as did Thucydides (*14*, I, 1–5), but he recognized the presence of want and some of its effects. The Lydians, he said, believed that half of their number had migrated to northern Italy because there was "scarcity through the whole land" (I, 94). The cause of this scarcity is not identified, nor is the reason why Ionians and others moved into Asia and there established an urban society (I, 142–151, 171–173).

He noted the disposition of apparently hard-pressed Greeks to settle as kleruchs (V, 77), or to seek employment with foreigners as workers (VIII, 26) or as mercenaries (I, 154; II, 154). He remarked the settlement of troops as colonists (II, 103) and the pressure of nomadic hordes upon one another (IV, 13). He reported that the Egyptian population had spread "as the land went on increasing" (II, 15) and gave drouth as the reason that the Theraeans considered colonizing Libya (IV, 151), although increasing Greek settlement there is credited (IV, 159) with dispossessing many Libyans of their land.

Colonization ventures usually had to have the sanction of an oracle (I, 165; IV, 155, 157, 159; V, 42). Herodotus refers several times to large-scale transfers of population of the sort that oriental empires often undertook (V, 12; VI, 3; also I, 170). Phoenician migration and colonization are mentioned (I, 1 ff.; II, 44; IV, 42 ff.). He questioned the Thracian assertion that mosquitoes prevented colonization of the country beyond the Danube, attributing its alleged inhospitality rather to the cold (V, 10). Cimmerian migration was attributed (I, 15) to Scythian pressure.

Herodotus did not distinguish sharply between a village society and an urban society, but he notes the impact of urbanization. He indicated that the Medes had lived in scattered villages and petty towns before the unification of Media, but later had built the large city of Agbatana (I, 96, 98). He implied that the society of the Greeks was a town society (for example, I, 146–149; V, 124; VI, 33, 44; VII, 109, 122 ff., 154). He described Assyria as studded with cities, the most renowned of which was Babylon (I, 178 ff.), and he described Egypt (II, 177) as containing "not less" than 20,000 "inhabited cities" (or somewhat more than the 18,000 villages and towns reported by Diodorus, *19*). Presumably, as a Greek, he greatly esteemed urban society above village societies.

Labor: Its Condition and Reward

Comments respecting labor, its productivity and its reward, are found in Herodotus. He noted the existence of division of labor but not the advantages attendant thereupon, advantages that Xenophon and Plato were to stress. He described the Egyptians as "divided into seven distinct classes . . . the priests, the warriors, the cowherds, the swineherds, the tradesmen, the interpreters, and the boatmen," each class as pursuing the indicated occupation (II, 164) (*20*). He supposed there to be little interclass mobility, for he said that the warriors were given solely to war (II, 165–166) and that occupations were hereditary among both the Lacedaemonians and the Egyptians. Sons "take their trades [heralds, flute-players, cooks, and so forth] by succession from their fathers . . . each follows his father's business" (VI, 60). Similarly with the priestly office (II, 37). Herodotus apparently was aware of disadvantages attendant upon this system, for he said it might prevent a young man with a loud voice from becoming a herald (VI, 60).

Priests and soldiers were held in highest esteem in Egypt. They were well paid. Each member of the warrior class was assigned 12 *aureae* (slightly more than nine English acres) "free from tax," together with other advantages on occasion (II, 168). The 1000 members of the king's bodyguard, in the year they served, received, "besides their aureae . . . a daily portion of meat and drink, consisting of five pounds of baked bread, two pounds of beef, and four cups of wine" (*ibid.*). Members of the priestcraft were "at no expense for anything" (including taxes), each being daily allowed bread baked "of the sacred corn . . . a plentiful supply of beef and of goose's flesh, and also a portion of wine made from the grape" (II, 37). The priestcraft was subject to certain sumptuary controls, being denied beans and fish (a food favored by Egyptians) and required to wear prescribed garments and observe practices insuring cleanliness (II, 37). Herodotus incorrectly stated that Egyptians ate spelt but not wheat and barley (II, 36).

Herodotus implied that the Egyptians, like the Greeks, were more favorably disposed to work and craftsmanship than were many peoples (II, 167). He refers to the "poor law" of Amasis, "that every Egyptian should appear once a year before the governor of his canton, and show his means of living; or, failing to do so, and to prove that he got an honest livelihood, should be put to death." He added incorrectly that this "excellent custom" was borrowed by Solon and imposed on the Athenians (II, 177). Herodotus, say How and Wells, exaggerated the Egyptian custom of "taking a sort of census of inhabitants and their occupations" and overlooked the fact that Solon both antedated Amasis and merely required (see *10*, XXII) that all sons be taught a trade (*3*, vol. I, p. 253; also *9*, pp. 137 ff.).

That Egyptian labor was relatively unproductive and that great mortality might accompany "gang labor" on public works are suggested. Thus he remarked that "no fewer than two thousand labourers" were required to convey a hollowed-out granite rock (21 by 14 by 8 cubits) from the quarry at Elephantine to Sais, 20 days' voyage away (II, 175). He stated that under Pharaoh Necho, 120,000 workers "lost their lives in making the excavation" that was to become a canal joining the Nile and the Red Sea (II, 158) (*21*), but he made no reference to mortality when discussing the canal that Xerxes had cut by Mount Athos (VII, 23–24, 122). Nor did he mention mortality when he stated that the construction of the causeway alone for Cheops' pyramid required the constant and oppressive labor of 100,000 men for ten years (II, 124) and that it cost 1600 talents of silver for the "radishes, onions, and garlick consumed by the labourers who constructed" this pyramid (*22*).

Wealth, Poverty, Happiness

Although Herodotus several times referred to poverty, noting that in "early times poverty was not confined to the people: kings themselves were poor" (VIII, 137), it is the ill effects of wealth and luxury rather than those of poverty that he emphasized. Thus, as he had earlier done with Croesus (I, 71), he has Pausanius contrast (IX, 82) the sumptuous fare of a Persian commander with the hardy fare of the Spartans and then ask why the former "needs come here to rob us of our penury." And yet he has Artabanus suggest to Xerxes that "there is no man . . . so happy, as not to have felt the wish . . . that he were dead rather than alive" (VII, 46; also I, 31). He subscribed to the view (as expressed by Rawlinson) that "victory is to the hardy dwellers in rough and mountainous countries, defeat to the soft inhabitants of fertile plains," a view expressed by Cyrus when he said that "soft countries gave birth to soft men" (IX, 122, and Rawlinson's note).

Elsewhere (I, 142; also III, 106) he implied that goodness of climate makes for goodness of character and institutions when he described the beauty of the "air and climate" of Ionia, somewhat anticipating Aristotle's view that the superiority of the Greeks was traceable to the equability of their climate (*23*). He made the Greek, Demaratus, say to Xerxes that "want has at all times been a fellow-traveler with us in our land," but added that the

Greeks' ally, "Valour," had enabled them to "drive out want and escape thralldom" (VII, 102). And he had Solon say to Croesus that, although riches made a man "better able to content his desires, and to bear up against a sudden buffet of calamity," they did not guarantee happiness; and that a man of "moderate" means had, besides more "good luck," the "following blessings: he is whole of limb, a stranger to disease, free from misfortune, happy in his children, and comely to look upon" (I, 32). The Persians, he stated, considered owing a debt the next "most disgraceful thing" to lying, since "the debtor is obliged to tell lies" (I, 139).

Miscellaneous Economic Matters

Here and there Herodotus touches on methods of production and other economic matters. He contrasted Egyptian and Babylonian agriculture and reported 200- to 300-fold grain yields in Babylonia, the country most fruitful in grain (I, 193; II, 14). He made absurd statements concerning gold production in India (III, 98, 102–106, 116), some of which were later repeated by Megasthenes (*20*, pp. 94–96) and others, but he wrote quite accurately about the Thasian mines which he had seen (VI, 46–47). He described albumen and oil production (VI, 119), canal excavation (VII, 23), and pontoon-bridge construction (VII, 36).

He explained the production of eunuchs in economic terms, saying that they were more valued by "the barbarians" than other slaves because they were regarded "as more trustworthy" (VIII, 105). He outlined the methods of embalming employed in Egypt (II, 85–89) and the irrigation-canal system developed there, together with the pharaoh's dependence on agricultural rents for revenue (II, 108–109). He depicted the lake-dweller type of habitat (V, 16) and discussed writing materials (II, 36; V, 58).

He described the Persians as quite ready to adopt foreign customs (I, 135), the Egyptians and Scythians as averse thereto (II, 91; IV, 76), and each people as preferring its own customs and faults to those of others (III, 38; VII, 152). He remarked on the origin of various customs (for example, V, 87–88; II, 105). He implied that wood-structured cities were highly vulnerable to fire (V, 101) and indicated that in the early days the Greeks had no household slaves (VI, 137).

He referred several time to rate of travel. He remarked that a vessel travels 70,000 fathoms in a "long day," or about one-fourth less than the 6 miles an hour a single merchantman might average (VII, 183). An army, he implied, moves at a rate about three-fourths of the 23 miles a pedestrian would ordinarily journey in a day (IV, 101, V, 53) and but a small fraction of the rate achieved by the Persian messenger service (VIII, 98); but he gave the rate of retreat of Xerxes' army as about 12 miles per day (VIII, 115), or double that of the advance (VIII, 51).

Political Theory

Herodotus (III, 80–83) put in the mouths of Persians Greek arguments for and against various forms of government. Otanes, rejecting monarchy because the king tends to set himself above the law and become tyrannical, advocates, instead, rule by the many (isonomy), with places assigned by lot, magistrates answerable, and measures resting with the commonalty. Megabyzus, rejecting monarchy and identifying democracy with rule by an unwieldy and ignorant rabble, advocates putting the government in the hands of "a certain number of the worthiest" citizens and establishing oligarchy. Darius, asserting the weaknesses of democracy and noting that enmity tended to rend oligarchies, advocates monarchy as the only long-run solution, saying that both democracy and oligarchy, upon succumbing each to its inherent weaknesses, tend to give place to monarchy. Herodotus looked upon the Persian governmental system as very hierarchical (I, 134), far more so than the systems found in Greece. Elsewhere (V, 29) he related how the conduct of the Milesian government was put in the hands of the ablest citizens.

Although Herodotus (III, 38; VII, 104) agreed with Pindar that "law is the king o'er all," with every people preferring its own customs to those of others, he anticipated the Hobbesian type of argument for a single ruler as a preventive of the "perpetual war" between "justice and injustice." He tells how one, Deioces, renowned for the fairness of his judgments, gave up hearing cases and administering justice (I, 96–97):

> Hereupon robbery and lawlessness broke out afresh, and prevailed through the country even more than heretofore; wherefore the Medes assembled from all quarters, and held a consultation on the state of affairs. The speakers, as I think, were chiefly friends of Deioces. "We cannot possibly," they said, "go on living in this country if things continue as they now are; let us therefore set a king over us, so that the land may be well governed, and we ourselves may be able to attend to our own affairs, and not be forced to quit our country on account of anarchy." The assembly was persuaded by these arguments, and resolved to appoint a king.

Herodotus must have reflected Athenian opinion when he expressed himself thus.

Various principles of statecraft are touched on

in *The History*. The scorched-earth military policy of the Scythians is described (IV, 46–47, 120). External war is said to make for internal tranquillity: "For thy own peace thou shouldst waste their strength lest idleness breed revolt against thy authority" (III, 134; also VII, 145). Despite the Persians' alleged condemnation of lying (I, 137), Darius recommends using the lie for personal advantage and as an instrument of state (III, 72; see also V, 97). Methods suitable for keeping a tyrant in power are indicated (V, 92). The existence of class struggles is little more than noticed (VI, 91). It is suggested that oracles might, if bribed, be induced to set up a desired state of expectations (V, 63; VI, 66). Freedom, by making every man "eager to do the best he can for himself," is said to make a people much more powerful than it would be if rendered submissive by life under tyranny (V, 78, 91; VII, 135). The struggle between barbarian and Greek is represented as one between slavery and freedom (VIII, 142–143; IX, 60, 98), between an army made up of slaves under the governance of the lash (VII, 56, 96, 103, 223) and an army of free men under the governance of law (VII, 104).

As Bury observes (*24*), the last division of *The History* is designed to bring out the superiority of Hellenic freedom and constitutionalism over oriental slavery and autocracy. A number of examples (IV, 161; V, 95; VI, 42, 108; VII, 154) disclose the practice and efficacy of intercity and intergroup arbitration. Although Herodotus sometimes referred to justice (for example, I, 137), he did not distinguish types of justice and give precision to their meaning, as Plato and Aristotle did later. He did not inquire why Greek political philosophy was not conducive to the development of an empire on the scale of the Persian or the Egyptian, much as the political philosophy underlying the Confederate states of America was unfavorable to their persistence as a power.

Use of Number

The manner in which number is used is probably the best index of the state of development of a social science. Herodotus made use of number, although sometimes in a misleading fashion. He stated the annual tribute received by the Persian king from each of his satrapies, putting its aggregate amount at 14,560 Euboic talents (III, 90–95), one of which was the equivalent in weight of £250 8s. 5d., pre-1914 value, according to Rawlinson. He indicated also that some of the satrapies furnished, in addition, white horses, eunuchs, corn, and fishery profits, and that irregular contributions in kind came from remoter dependencies (III, 97) concerning which, however, he offered little quantitative information (III, 96–117).

He referred to the king's accumulation of gold and silver but did not estimate its amount (III, 96), which one modern author has conjectured (*15*, pp. 1 ff.) to have approximated 180,000 Persian talents. (Plutarch put the amount found in Susa at 40,000 talents in "coined money" alone [*16*, XXXVI]). His account (VII, 61–99) of the tribal contingents composing Xerxes' army and fleet, the vessels of which are enumerated, together with his list of satrapies (III, 90 ff. and his description of the Royal Road (V, 52 ff.), has been described as "our best authority for the ethnography of the Ancient East," 61 of whose peoples he identified (*3*, vol. 2, p. 151).

His estimates of the size of Xerxes' forces illustrate, as do Megasthenes' estimates of Indian military strength (*20*, frag. LVI), Samuel Johnson's dictum that numbers are always magnified when the ancient method of guessing is used instead of the modern practice of counting. Xerxes is represented as enumerating his troops by having them pass into and out of an enclosure holding so many (VII, 60), that is, by recourse to a method reminded of that whereby the Scythian population was estimated from the piles of arrowheads resulting when one head was supplied by each man (IV, 81). Herodotus (VIII, 185) put Xerxes' fighting forces at 2,641,610, of which about four-fifths were ground troops, and then doubled this figure (V, 186) to allow for attendants (exclusive of ordinary camp followers) upon fighting men.

He presented more sober estimates, however, when he put at 300,000 the army of Mardonius, by which most of the fighting was done (VIII, 101, 113; IX, 32), and when he gave the forces opposed at the battle of Plataea as 300,000 Persians and 50,000 Greeks in Mardonius' army and 38,700 hoplites and 69,500 light-armed troops in the opposing Greek army (IX, 28–30, 32, 70). Delbrück's suggestion (*25*) that Xerxes' army might have numbered no more than 15,000 is criticized by Wells (*4*, pp. 146–149) and by How and Wells (*3*, vol. 2, pp. 363–368), who estimate the Persian ground forces as falling between 180,000 and 300,000, Mardonius' army at less than 150,000, and the number of Persian fighting ships at about half of that given by Herodotus. F. Maurice (*26*) estimates the size of Xerxes' forces at about one-twelfth of the number reported by Herodotus. Herodotus' account of the organization of the Persian army is considered basically valid, although his application was in error (*4*, pp. 149 ff.).

It is strange that Herodotus passed over the logistical limitations that operated, in his day, to restrict

the size of military forces. He not only noted the planning entailed (VII, 20–21, 25) and made one of Xerxes' counselors emphasize the inability of Greece to feed an army of the dimensions given, or to furnish safe harbors for the accompanying fleet (VII, 10–11, 48–50), but also reported that it cost Greek cities on the invasion route 400 silver talents to furnish the host with a single meal (VII, 118–119). He estimated the daily corn requirement of the army (exclusive of that of the women, eunuchs, sumpter beasts, and hounds) at 165,510 bushels (that is, at one-ninth of Attica's wheat production in a good year [*27*, vol. 1, p. 90]). He remained content, however, to marvel that "the provisions did not fail" (VII, 187).

Herodotus exaggerated greatly in other instances when he resorted to quantity. He put Darius' ground forces at the conventional (*3*, vol. 1, p. 333) figure of 700,000 (IV, 87). He made the odds against the Greeks at Thermopylae prodigious (VII, 228; VIII, 24–25). He repeated native reports that 700,000 attended an Egyptian feast (II, 60). He must have greatly magnified the loss of life attending excavation of the Nile-Red Sea Canal (II, 158; see also *3*, vol. 1, p. 246). His interpretation of reports of the labor-cost (II, 124) of constructing the pyramid of Cheops probably exaggerated this cost (*3*, vol. 1, pp. 227–228; *22*), as must also his statement of the cost of supplying the workers with onions, garlic, and radishes (II, 125). Sometimes he exaggerated war losses even when he gave no numbers (VII, 170).

Conclusion

It is a truism that men behaved economically long before they philosophized about it. There is a great deal of descriptive matter pertaining to economic behavior in *The History*, some of it flowing from Herodotus' geographic interests, but very little philosophizing about this matter. In some measure this is to be expected—even in Gibbon one encounters a paucity of economic principles—and was characteristic even of later historical writers, for example, Polybius. The primary concern of the author was to relate, in a pleasing manner, what happened and what was alleged to have happened with respect to the origin and the outcome of the Persian War. At the same time, had there been at hand explanatory economic principles, he might have better accounted for some of the events that did happen and might have avoided some of the errors that he made, such, for example, as his neglect of the logistic limitations to the size of an army that the Persians could put in the field. Even so, one would not have found him reflecting a spirit of capitalism.

Herodotus had no notion of an economic system and, hence, could say little about pricing and distribution. He did not emphasize the role of economic forces, as Plato did later, but stressed, rather, personal and political factors, as when he has Xerxes seeking world hegemony (VII, 8, 19). Although he noted the importance of pursuit of personal advantage, he gave it economic form only on rare occasions (for example, VII, 158). He failed to inquire why peoples such as the Persians and the Egyptians could organize large empires and utilize large bodies of men in the construction of public works, perhaps because he believed this capacity to rest upon slavery and the denial of liberty as conceived of by the Greeks. He did not appreciate the politico-economic revolution that was making an England out of Greece and, so, he did not anticipate the economic collapse that would take place when Greece lost the trading advantages she was winning in his day. He was not particularly sensible of inconsistency between the dimensions of the city-state and the dimensions of the world whereof he wrote. He was above all a historian rather than an economist.

References and Notes

1. E. H. Blakeney, Ed., *The History of Herodotus*, G. Rawlinson, Trans., in Everyman's Library (Dutton, New York, 1936). Although the Rawlinson translation has been used, A. Godley's translation of *The History*, included in the Loeb Classical Library, has been consulted. Herodotus' sources are touched upon in the works cited in notes 2, 3, 4, and 24. See also L. Pearson, *Early Ionian Historians* (Clarendon, Oxford, 1939). *The History* is divided into "books" and numbered paragraphs. In the references to *The History* that are given in the body of this article, the Roman numeral identifies the book referred to, and the Arabic numeral specifies the numbered paragraph in the book that is being cited. Citations from the works of Diodorus Siculus, Pliny, Plutarch, Strabo, and Thucydides are from the editions included in the Loeb Classical Library; the mode of citation in this paper follows the breakdown into numbered books and/or paragraphs (or sections) of the work cited.
2. J. E. Powell, *The History of Herodotus* (Cambridge Univ. Press, 1939).
3. W. W. How and J. Wells, *A Commentary on Herodotus* (Clarendon, Oxford, 1912), 2 vol.
4. J. Wells, *Studies in Herodotus* (Blackwell, Oxford, 1923).
5. On the nature and extent of silent trade, see E. E. Hoyt, *Primitive Trade: Its Psychology and Economics* (K. Paul, Trench, Trubner, London, 1926); P. J. H. Grierson, *The Silent Trade* (Green, Edinburgh, 1903); M. Mauss, *Essay on the Gift* (Free Press, Glencoe, Ill., 1954).
6. Pliny, *Natural History*, VI, 88.
7. H. Michell, *The Economics of Ancient Greece* (Cambridge Univ. Press, 1940).
8. A. J. Toynbee, *A Study of History* (Oxford Univ. Press, New York, 1934–54), 10 vol.
9. K. Freeman, *The Work and Life of Solon* (Univ. of Wales Press, Cardiff, 1926).
10. Plutarch, *Solon*, in Plutarch's *Lives*.
11. Strabo, *The Geography*, VIII, vi, 20 ff.

12. M. Cary, *The Geographic Background of Greek & Roman History* (Clarendon, Oxford, 1949), pp. 80–84.
13. Xenophon wrote (*Cyropaedia,* I, ii, 3): "The hucksters with their wares, their cries, and their vulgarities are excluded from this to another part of the city in order that their tumult may not intrude upon the orderly life of the cultured." Herodotus' translator Rawlinson himself appended this note to the passage cited: "Markets in the strict sense of the word are still [in mid-nineteenth century] unknown in the East, where bazaars, which are collections of shops, take their place. The Persians of the nobler class would neither buy nor sell at all, since they would be supplied by their dependents and through presents with all that they required for the common purposes of life. Those of the lower rank would buy at the shops, which were not allowed in the Forum, or public place of meeting."
14. Thucydides, *History of the Peloponnesian War.*
15. H. Michell, "The Impact of Sudden Accessions of Treasure upon Prices and Real Wages," *Can. J. Economics and Political Sci.* **12**, 1 (1946).
16. Plutarch, *Alexander,* in Plutarch's *Lives.*
17. This passage is translated as "had wrongful intercourse with her" by A. Godley in the Loeb Classical Library edition of *The History*; it may be rendered literally, "intercourse not according to custom."
18. V. G. Childe, *Prehistoric Migrations in Europe* (Institutet for Sammenlignende Kulturforskning, Oslo, 1950).
19. Diodorus Siculus, *Library of History.* "In ancient times," says Diodorus (*ibid.,* I. 31), Egypt "had over eighteen thousand important villages and cities," and "over thirty thousand" from around 300 B.C. to the period at which he was writing, 56 B.C. and thereafter. Egypt's population "was of old about seven million and the number has remained no less down to our day."
20. This classification resembles somewhat that which Megasthenes later reported for India. He reported seven castes: philosophers, husbandmen, neatherds and shepherds, artisans, military, overseers, and counselors and assessors. Hunters appear to have been included in the third category, and vendors and persons engaged in manual labor with the artisans. See J. W. McCrindle, Ed., *Ancient India as Described by Megasthenes and Arrian* (1876–77) (Chatterjee, Calcutta, 1926), pp. 38–41, 82 ff.
21. How and Wells (reference 3, I, p. 246) believe the loss of lives exaggerated, since "Mehemet Ali lost only 10,000 in making the Mahmudieh Canal (from the Nile to Alexandria)."
22. Herodotus apparently meant that a levy of 100,000 men would be engaged in transporting stones for 3 months and then replaced by a similar levy, with the result that 400,000 men worked, each one-fourth of a year. This number apparently does not include the masons and their helpers who worked the year around. See I. E. S. Edwards, *The Pyramids of Egypt* (Penguin, Harmondsworth, 1952), pp. 229–30; but see also How and Wells, reference 3, I, pp. 227–228.
23. Aristotle, *Politics,* VII, vii, 2–3, 1327b.
24. J. B. Bury, *The Ancient Greek Historians* (Macmillan, New York, 1909), p. 44.
25. H. Delbrück, *Numbers in History* (Univ. of London Press, London, 1913), p. 61.
26. F. Maurice, "Size of the Army of Xerxes in the Invasion of Greece," *J. Hellenic Studies* **L**, 210 (1930), 210 ff.
27. G. B. Grundy, *Thucydides and the History of His Age* (Blackwell, Oxford, ed. 2, 1948), vol. 1, p. 90.

The industrial revolution has not only changed the nature of war as a technic, but it has also changed its political character. It is no longer a calculable instrument of politics, capable of achieving the aims for which it is waged, but escapes control and becomes a universal mechanism of disturbance not only for the belligerent nations but for all others as well. Once understood, this great historical fact must ultimately lead to the renunciation of war as an instrument of policy. Even the Hitlers of the future may hesitate to use it for their own advantage or that of a nation whose destinies they direct. There is no more compelling task at the present time than to make sure that this inevitable lesson of the nature of modern war is driven home in the minds of all thoughtful people in every land.—JAMES T. SHOTWELL.

Beauty and the Beast: Life and the Rule of Order

PAUL WEISS

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SAID the Beast to Beauty, "Your poor Beast would die of grief for your absence; I could not live without you."

Said Beauty to the Beast, "You shall live to be my husband, for I really love you."

And so, according to the story, beauty and animal became united and have been one ever since. Quite naturally. For, beauty is order; life is order; hence life is beauty. It is a syllogism—that simple.

I say there is beauty in the living form. Let me call my witnesses. First, yourself.

This is one of Haeckel's superb drawings from his *Kunstformen der Natur* (1), a medusa, which shows all the attributes of beauty that G. D. Birkhoff has enumerated in his treatise on *Aesthetic Measure* [Harvard Univ. Press, 1933]: symmetry, balance, rhythm, and, I may add, a pleasing ratio of constancy and variety. You will concede its beauty.

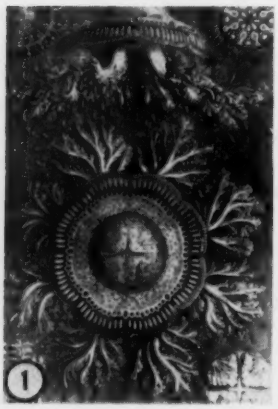
Or take this next design (2), which is not part of an oriental temple, but the radula of a snail. To scan its rhythmic and well-proportioned structure is surely an esthetic pleasure.

Next witnesses, the artists, who turn to living nature for models of their patterns. Young ferns like these (3) no doubt inspired the ornamental staffs of shepherds and bishops (4), just as the dried stems and leaves of common garden plants (5) have served as prototypes for such decorative art as this Gothic wrought ironwork (6). The gradient of density from center to margin shown by the branching pattern of the veins of leaves (7) is utilized in this antique vase (8).

What all such objects have in common that underlies and makes us sense their beauty is their display of regularity and consistency; regularity expressed in such features as symmetry, repetition, and alternation of elements; and consistency, as in the use of curves, proportions, size gradients, and so forth, in subdividing space. In short, we sense the rule of order over randomness, of pattern over chaos, of law over accident. The patterns we perceive are of both space and time.

This 12th-century Japanese scroll (9) may illustrate the artist's use of angles, periodic interruptions, and regular, though not rigid, disposition in space of units to create an impression of harmony. If for a moment you view these trees as scales on fish skin, you will see the link between this canvas and our living objects.

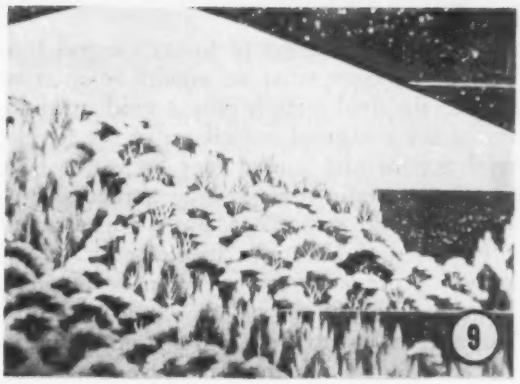
Now, take the next scroll (10). It shows the very same rhythmic arrangement of elements, but this is no longer a static space pattern; it is rhythmic motion, arrested for a split second and frozen into

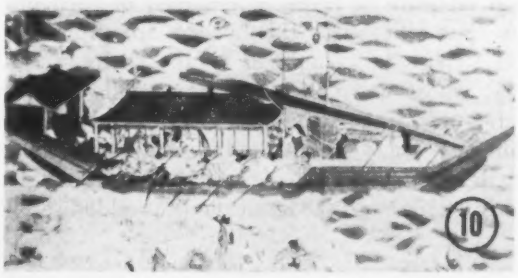


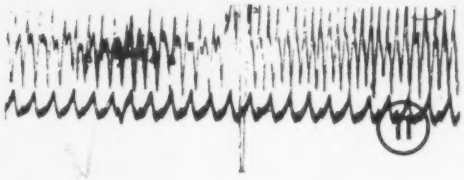
a picture: time order translated into spatial dimensions.

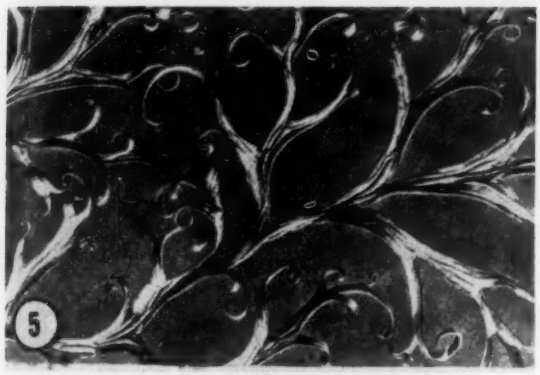
A rhythmic process, recording its own beats on a moving tape, thus writes a wave pattern in space that is instructive and at the same time beautiful, as in these records of periodic nerve discharges from lobster ganglia (11). There is really no fundamental difference between the family of curves that represent the tracings of successive reflex discharges (12) and the curvilinear designs on shells and other growing structures (13), for both are but residual tracks in space of sequences of events repeated in regular succession: time interval transcribed to space interval.

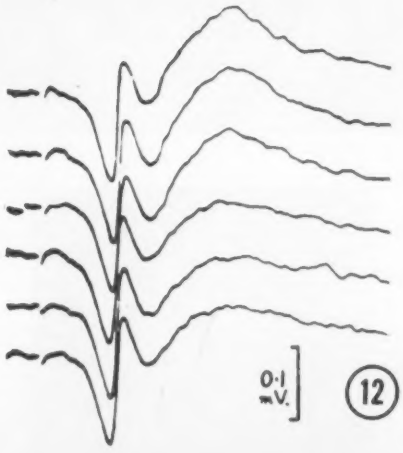
This leads me to my central theme. In the last analysis, whatever organic form we view has had its history and has come to be what it is through long sequences of developmental processes. And

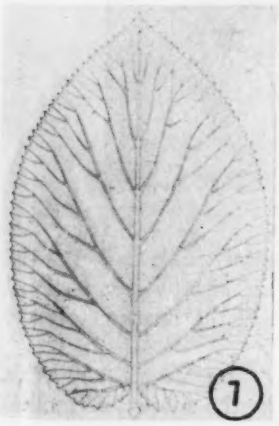






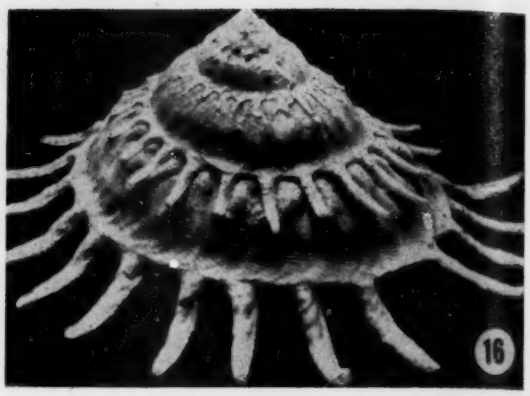






since all form is thus merely a momentary cross section through a stream of formative and transformative processes, what we admire as order and beauty in the final form is only a product and an index of the measured orderliness of the developmental actions and interactions by which it has come about. Static form is only a precipitate of underlying and antecedent formative dynamics. Goethe called architecture "frozen music." In the same sense, organic form is frozen development; and formal beauty reflects developmental order.

Just as trees record their spurts of growth as tree rings, so do many animals preserve a record of their periodic growth in hard deposits, such as shells or horns or nails. The beauty of such products thus epitomizes the law of growth. This is most strikingly exemplified by the shells of snails (14), whose convolutions grow steadily in width as they add to their length. Conveniently some of them beat time, as it were, by marking equal intervals by ridges (15) or spines (16) or horns (17); and if we measure the segments thus added serially,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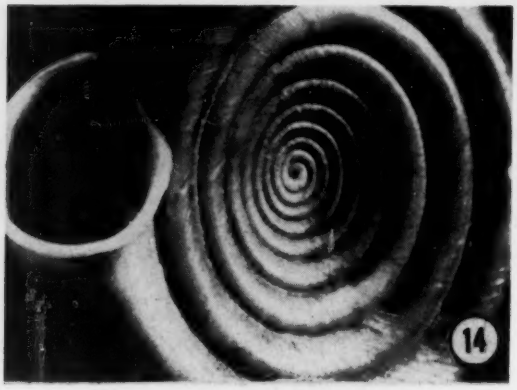
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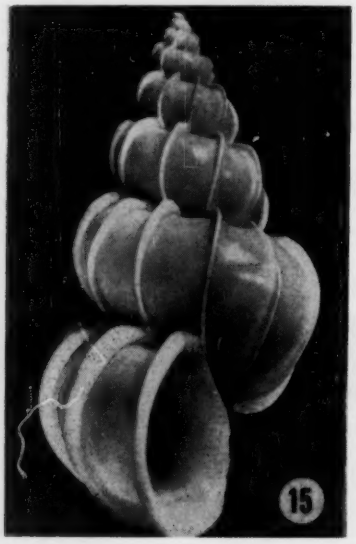
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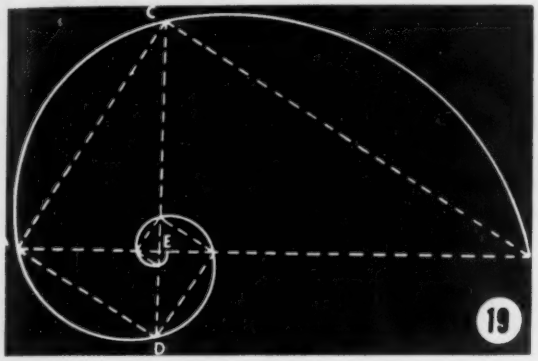
we note, as in this section through a shell (18), that each new one is an exactly proportional, though magnified, version of the immediately preceding one.

It is not surprising that for nearly 250 years, since the days of Réaumur, the subject of mollusk

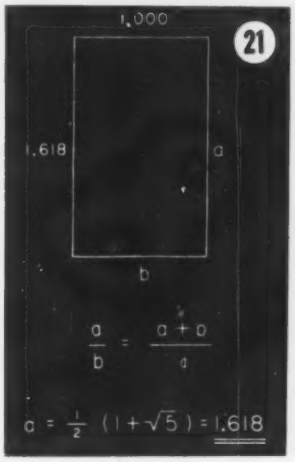
shells has attracted the joint attention of biologists, mathematicians, and students of design. In general, this growth pattern conforms to a curve known as a logarithmic spiral, or equiangular spiral. It has many remarkable properties, for instance, the one shown in this diagram (*19*), which illus-



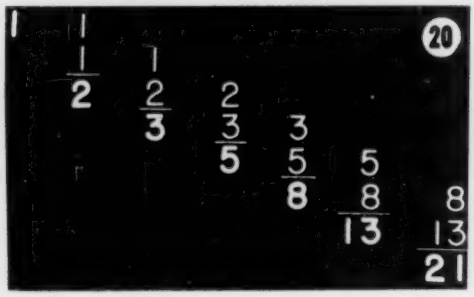
trates that the ratio of any two successive segments meeting at identical angles (in this case 90°) is constant. As the curve lengthens or "grows," geometric similitude of successive sectors is preserved. What this implies in actual fact is simply that the width of the turns increases at a fixed ratio to their length. This is indeed what one senses directly by looking at the section of the shell. The curve merely confirms and gives precision to one's immediate impression.

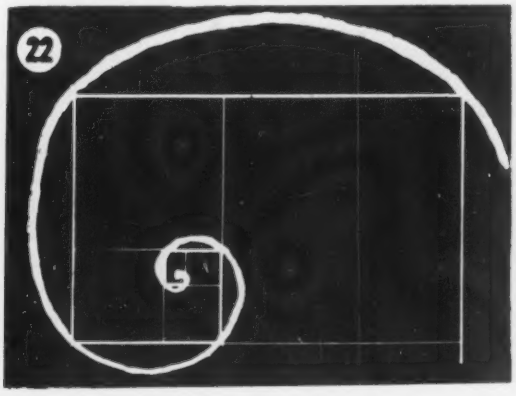
The beauty of the shell, which lies in its law of growth, has thus been reduced to mathematical formulation. This is pertinent. But let me add at once that in past efforts at reducing form to formulas, there has been a notable streak of plain numerology, conjuring mystical numerical properties of the structure of the universe. Some of these formulas came close enough to the truth; for instance, successive growth installments in our snails fit roughly the so-called Fibonacci series, in which each member is the sum of the two immediately preceding ones (20). This same series applies to the phenomenon of phyllotaxis in plants. Yet, on closer inspection of the series, we note a peculiar property: the ratio between any two successive members tends to become nearly constant as it converges upon a mean value around 1.618. The real crux of the matter is then this constancy of ratio and this, in turn, stripped of all sophistry, is simply a reaffirmation of the law of logarithmic growth.

The value of 1.618 has in turn been the subject of serious, as well as playful, speculation. It is related to what the Greeks termed the divine section, now better known as the golden mean. It gives the proportions of a rectangle in which the smaller side bears the same relationship to the larger one as the larger one bears to the sum of both (21). Art and architecture of the antique



and Renaissance have made ample use of this highly satisfying proportion. But its biological sense lies in its intrinsic relationship to the logarithmic spiral. For if we erect a square over the larger side, the resultant bigger rectangle has again the same proportions as the first, and repeating this procedure on and on, one obtains a series of superimposed rectangles that define a logarithmic spiral (22).

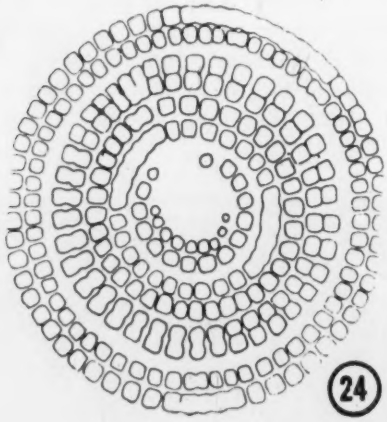




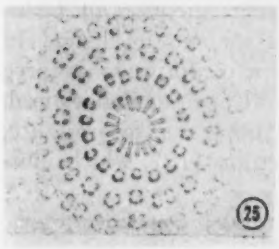
This linking of geometry and growth makes valid sense. We cannot say the same of such playful exercises as applying harmonic analysis in terms of the golden mean to human face and figure (23); although this has been dignified by the masters of the antique and Renaissance, it can hardly be justified as biologically meaningful.

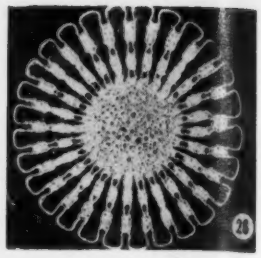
Our theme, that the beauty of forms rests on the lawfulness of their formation, has many variations. Of these I can sample only a few. They all relate to geometrically regular systems of lines or points.

Let us choose first a simple type of polar patterns, those organized around the circle and its radii. A starch grain, when swollen, breaks into smaller units stacked in concentric layers with marked radial alignment (24). The same design



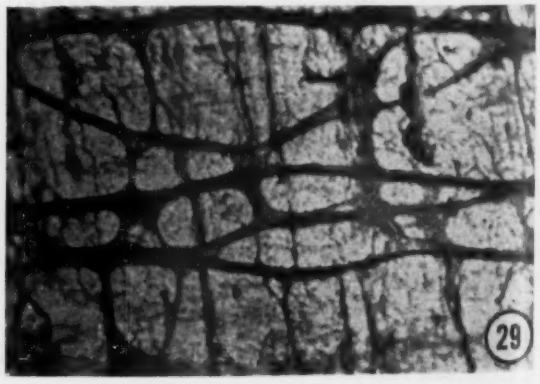
returns in the skeletal arrangement of this disk-shaped diatom (25) and perhaps even more handsomely in the cross section through the spine of a sea urchin (26). Note the beautiful concentric, as



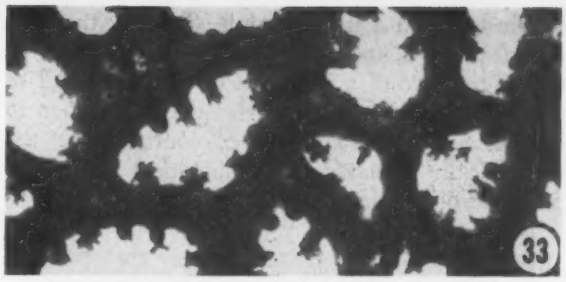


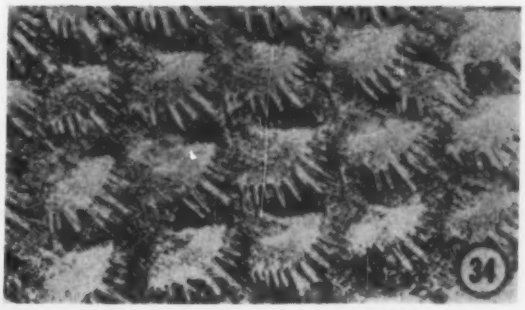
well as radial, regularity, which is not impaired in the least—indeed, perhaps it is accentuated—by the minor deviations and imperfections of local detail. Other examples of rhythmic concentric patterns are sense organs of the skin (27) and the Haversian systems of bone (28).

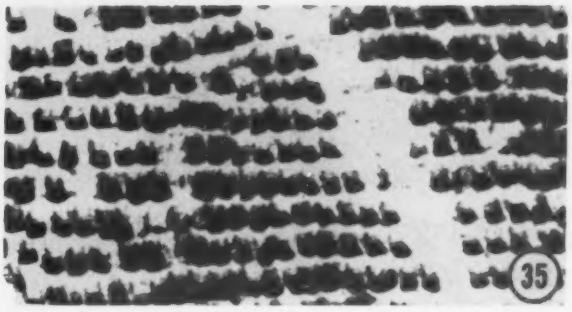
Since radius and circumference intersect at right angles, these circular patterns are actually but a special case of the more general principle of orthogonal intersections, that is, of patterns of lines crossing at right angles. The nerve plexus of the intestine well illustrates this pattern of warp and woof (29). The fine orthogonal tracery of the spongy part of our bones (30) is similarly organ-

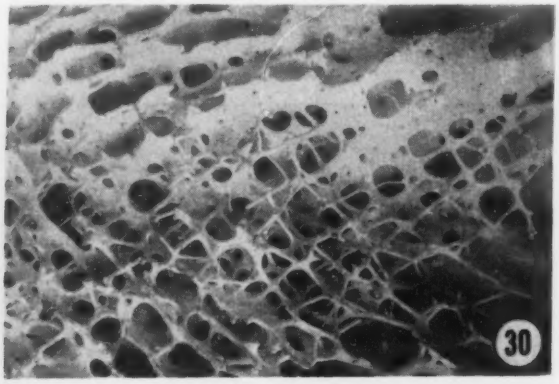


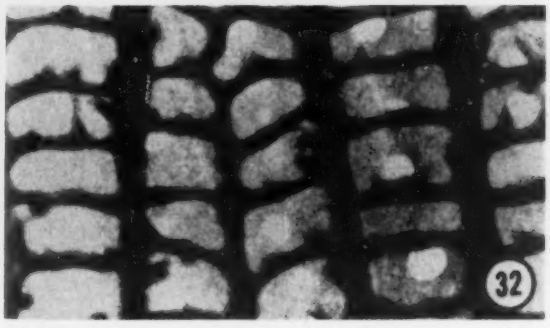
ized. These gross or microscopic textures are matched on the submicroscopic level by a remarkable orthogonal fabric which we discovered a few years ago under the electron microscope; this is the basement membrane of the amphibian skin (31) consisting of about 20 layers of collagen fibrils neatly stacked up with alternating orientations. (To indicate the magnification, the height of the illustration corresponds to about 5 microns). Likewise on the electron-microscopic level is this picture of the chitinous framework of a scale of a moth's wing (32). The major ridges are cross-linked by braces in rather regular fashion with just enough variation to make the picture interesting. Now, climbing back to more conventional dimensions, we rediscover essentially the same pattern







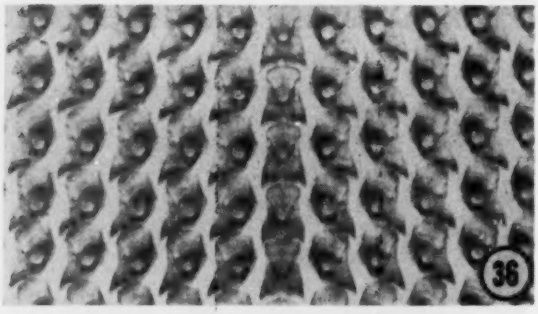


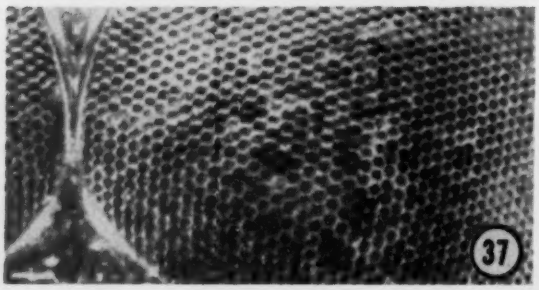


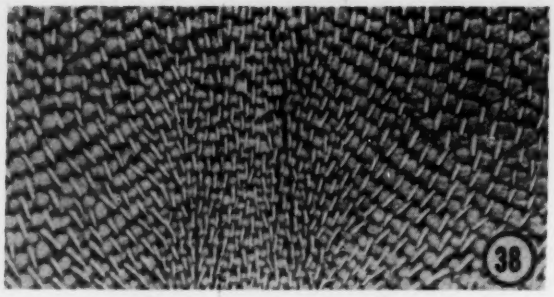
in this community housing project of the lace coral (33).

The manifest tracts of fibers or skeletons in the preceding pictures should again be viewed as the embodied histories of their development—the nerves, of the directions along which they had grown; the collagen fibrils, of the forces that had aligned them; the bone spicules, of tension and pressure systems; the corals, of the polarized building activities of the colony. Now, instead of depositing such immediately visible precipitates, the developmental grid may merely set off, at nodal points of its fabric or lattice, new secondary processes of growth and differentiation. For instance, the scales in the skin of fishes (34) seem to emerge at intersections of two periodic line systems, and so do the papillae in the feather tracts of birds. The process reminds us somewhat of the tacking of tiles to a roof. The analogy of shingles is obvious when one looks at the scales on the wing of a butterfly (35). And even neater grids are shown

by the teeth on a snail's radula (36), by the hexagonal array of facets in the insect's eye (37), or by the papillae of a leopard's tongue (38). All of these examples contain one element in common to both beauty and soundness of construction: the rhythmically repeated use of identical parts—the principle of *periodicity*.

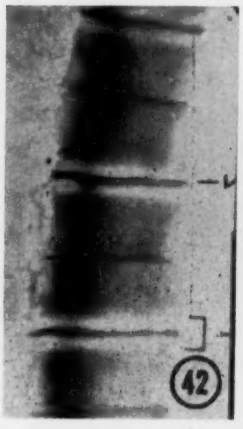






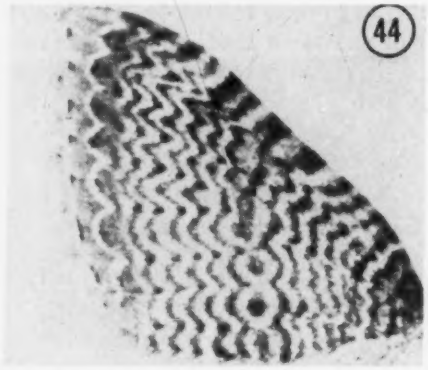
The esthetic value of this principle is borne out by its common usage in artistic compositions. In this Japanese painting (39), for example, the planks form a primary repeat pattern, with three pairs of nails in each giving a secondary rhythm. Repeat patterns like these characterize organic structure from its molecular units up to the spinal column of the dinosaur. A fiber of collagen under the electron microscope (40) shows regular segments, 640 angstroms long (the stretch of fiber seen here measures less than 2 microns from top to bottom). Compare this with the banding of a caterpillar (41) in which each segment is of the order of several millimeters, with secondary bands marked in between. Returning to the electron

microscope, note the similar appearance of an individual fibril of cross-striated muscle (42), with segments less than 1000th of those of the insect larva. Back to the macroscopic, we see the principle of major and minor periods once more pro-



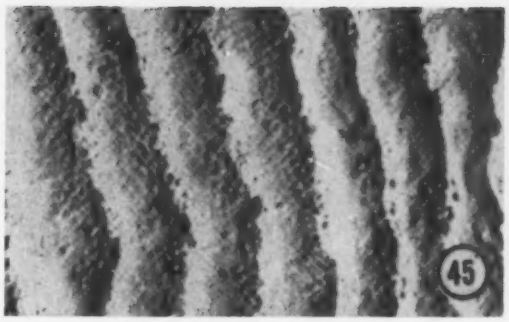
jected in the versatile mollusk shell (43). And last, the familiar rhythmic banding of the lepidopteran wing (44).

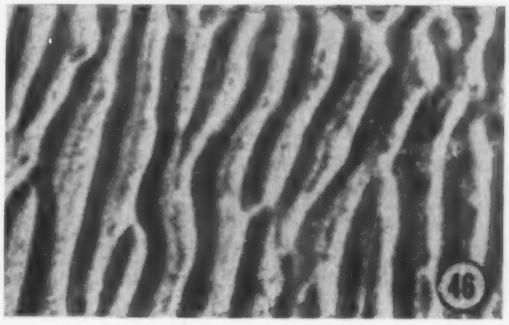
In presenting these examples I have made no distinction between the ways in which these various rhythms are produced. In some instances, they arise by the linking and stacking in register of units of standard size into long chains and bundles, as in collagen and muscle; in others, the rhythms are due to alternating ups and downs of growth rates, as in shells; and in still others, they may result from spreading wave actions, as has been variously suggested for the wing designs of moths and butterflies. A wave pattern is pleasing by its rhythmic alternation of dark and light, or high and low, expressing regular pulses of events in orderly relationships, synchronized in time or linked in space. For, this is what a wave front means: all points along the front are beating in unison and pass their rhythm on to the rest of the system. The system thus submits to coordination, in contrast to anarchic behavior, in which each element arbitrarily sets its own phase and its own pace of action unrelated to the others, the whole becoming a blur of randomness with no design whatever. On the other hand, we must not forget that even the regular wave, when viewed from close range, will at any one moment show capricious singularities that will



never recur in quite the same form. In other words, order in the *gross* does not rule out uniqueness of *detail,* and vice versa.

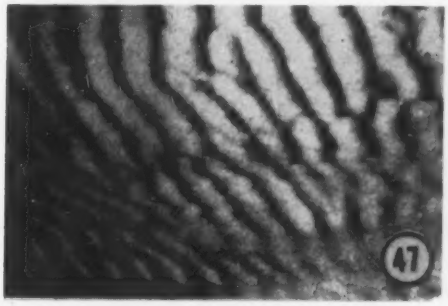
The origin of wave forms is very diverse. Waves are prominent in this microscopic shadow cast of the enamel surface of a tooth (45) with ridges and valleys like the Allegheny Mountains. Note how closely this pattern resembles the ridges or dunes in windblown sand (46), which owe their origin to wholly different dynamics. Let me stress once again in this picture the great over-all regularity that pervades this pattern consistent with the minor faults and deformations here and there.

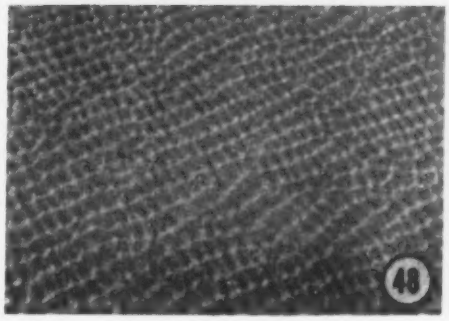




The streaks of clouds on a mackerel sky (47) reveal the same morphology, and yet a third type of dynamics underlies their pattern. If water waves from two directions cross each other, they leave the impress of their interactions in the plastic sand at the bottom in a grid of intersecting lines with nodes (48) not unlike the grain of lizard skin.

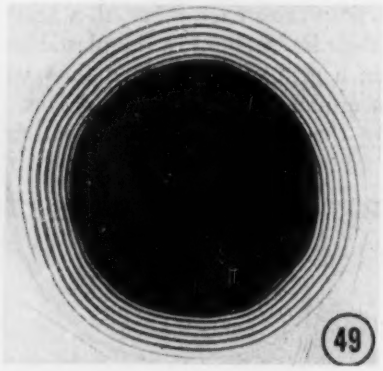
Clearly, the beauty of all these patterns resides





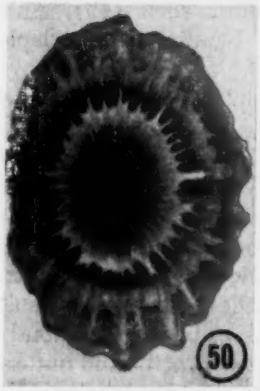
in the formal similarity of their dynamics, regardless of the nature of the agents and vehicles. To realize this helps us to gain a balanced attitude toward nonliving models as analogs of biological processes: an attitude of neither shunning them for fear they be mistaken for the real thing, nor, on the other hand, falling for the delusion that they may be the real thing after all.

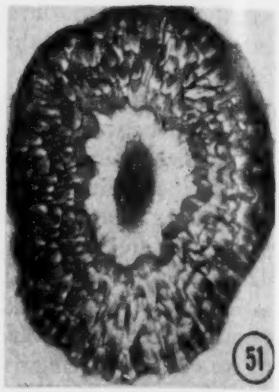
When Liesegang first showed that continuous diffusion in jellies may automatically lead to discontinuous rhythmic precipitations, the well-known Liesegang rings of colloidal silver (49), this was promptly adopted as a possible explanation of rhythmic band patterns in animals, for instance, in lepidopteran wings. It proved to be a too simple assumption. The coloring agent melanin does not itself spread in this fashion. And yet the principle is still correct. It seems established now that certain local regions of the wing issue a process, call it induction or transmission or conduction of something still unidentified, that spreads over the wing in wavelike fashion, thus causing alternating bands of the scale cell population to produce melanin or not, depending on whether they were at the crest or valley of a wave. So, models of the Liesegang ring type do have some biological pertinence.

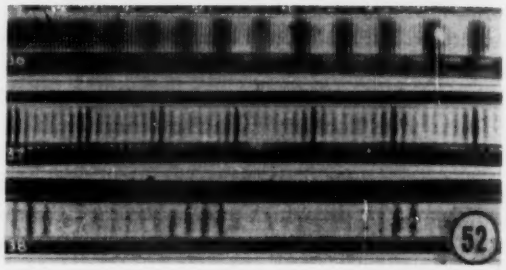


I cannot resist the urge to offer a glimpse of the complex order and beauty of rhythmic diffusion and precipitation patterns involving colloids (50, 51). These are two samples from a collection in my possession of chemical reactions on filter paper prepared nearly 100 years ago by Runge—the first paper chromatograms.

Diffusion in jelly-filled tubes gives Liesegang bands with major and minor periods (52). This discontinuity is a threshold phenomenon, for only at a certain distance from an established band can silver grains reach the requisite threshold concentration to form another band. In its general character, this is a valid model of numerous rhythmic processes in biological systems. Their prototype

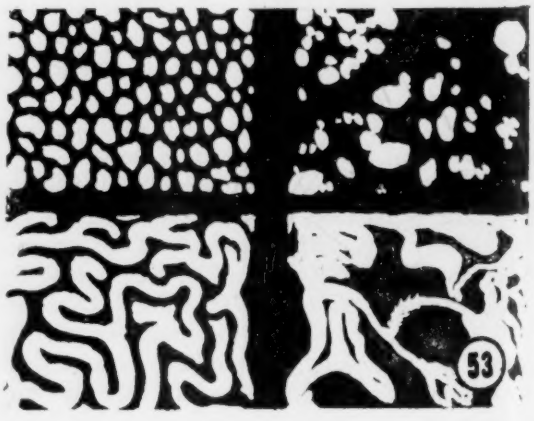






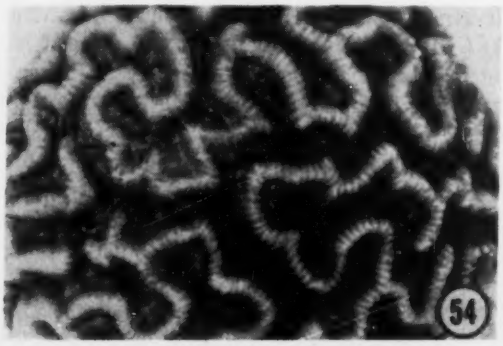
is the dripping faucet, where water feeds the drops continuously, but drops will break off only periodically as their weight overcomes cohesion. In morphogenesis we may expect such patterns to arise wherever local processes are in competition for something from their surroundings, so that another process of the same kind would have no chance to get started concurrently, except at a safe distance where it can assert its own competitive strength. As a result, there will be blank, no man's lands spared out between the active centers, dividing the space continuum into harmonious patterns of rhythmically alternating properties.

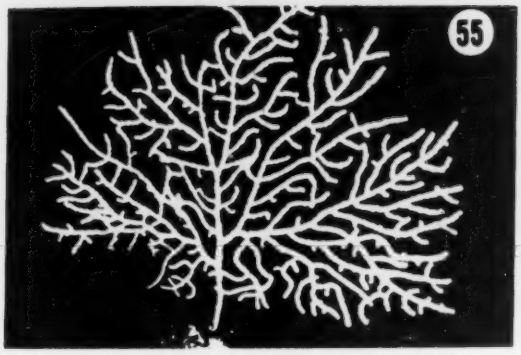
The types of patterns resulting from such group dynamics can be diagramed (53). The lower quadrants show two patterns of continuous lines: the right one, of random dimensions and distribu-



tion; the left one, of more regular arrangement, the rule of order being that the line retains its average width and remains separated from itself by a standard margin. The top part of the diagram shows this same principle for discontinuous systems. The esthetic superiority of the left over the right panels is immediately apparent. Although the lack of symmetry marks them as of a lower degree of order than that of our previous examples, they still contrast agreeably with the disordered randomness of their right counterparts.

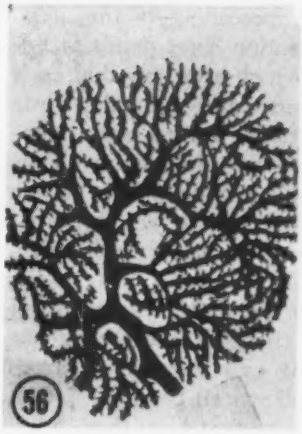
A few examples may illustrate how this principle of harmonious space filling has been implemented in organisms and their parts. This brain coral (54) looks like a direct embodiment of the symbolic line pattern of the last diagram. Note how this sea fan coral (55) distributes its branches with

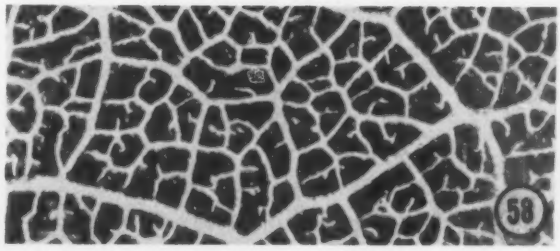


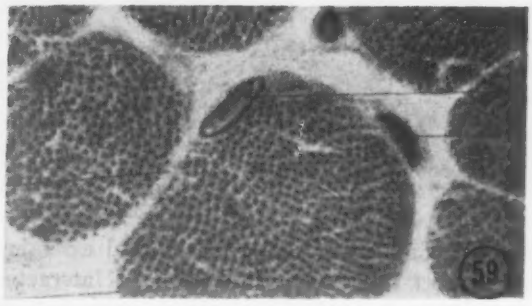


the same average density throughout the structure, with no big holes nor overcrowding anywhere. The same pattern is found here in the dendritic processes of a single nerve cell of the cerebellum (56), or in the gastrovascular arborizations of the fluke (57), or finally, perhaps the prettiest of them all, in the venation of a leaf (58). All these are continuous line systems, branched with or without anastomosing, but always of regulated density.

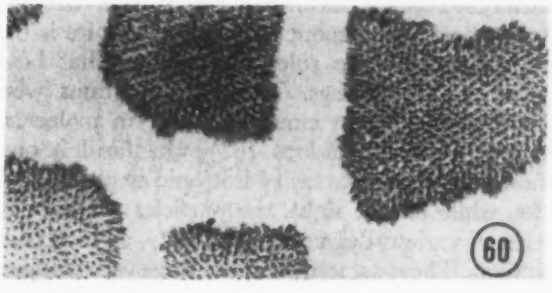
Next is an example of harmonious but discontinuous filling of a given space. This cross section through a muscle (59) shows the individual large





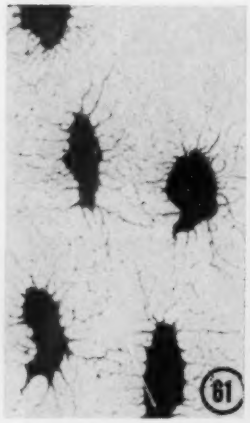


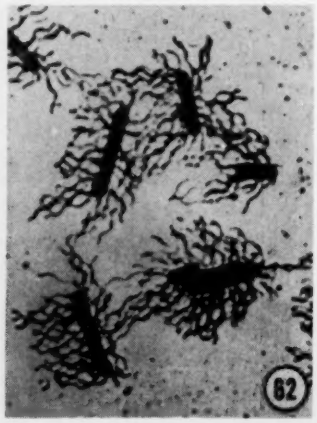
muscle fibers set off in space, keeping their distance. If we single out one such fiber, we note that it is dotted with smaller discrete elements, the myofibrils appearing in cross section as black stippling. Now, we may pick out one such black dot and magnify it enormously under the electron microscope (60). A whole island here corresponds



to one little dot of the preceding picture (the whole width of the illustration corresponds to ap--proximately 1 micron). We observe now that each fibril is once more subdivided into a regular array of smaller units hexagonally packed and tentatively identified as the contractile protein chains of myosin and actin. So, exemplified here is one and the same principle of orderly packing repeated in three magnitudes, from the macroscopic down to the molecular.

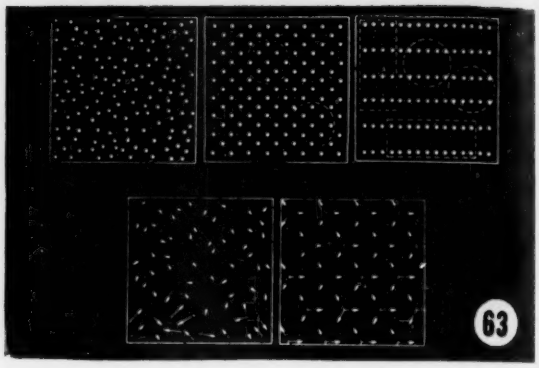
The order in this case is a visible expression of the interaction between the constituent elements, which, in a sense, keep one another at arm's length. As we look at well-spaced bone cells (61), we can literally see the arms that keep them apart in the ground substance, and the same is true in this picture of flagellated bacteria (62). However,



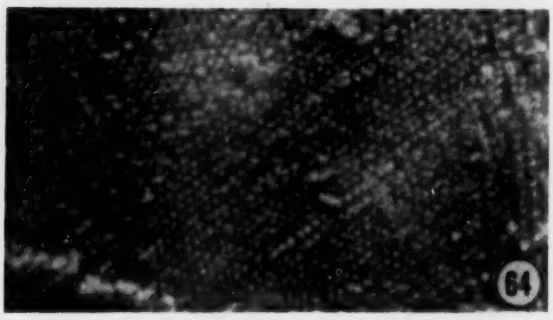


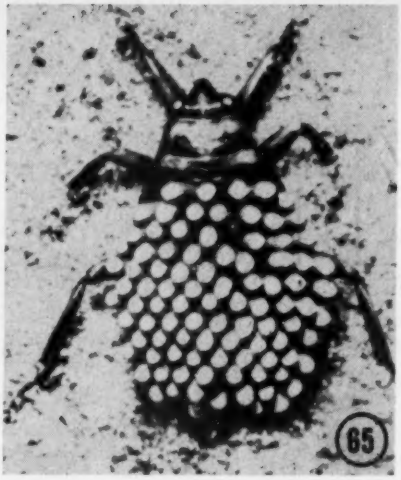
what appear here as visible mechanical extensions are in most other cases just fields of interacting forces that stake out the territory of a structure and keep it clear of the intrusion of another like it. Once more, esthetic design has yielded to resolution to terms of orderly dynamics.

Now, where does all this lead us? The common element of appeal we have discovered in these manifold patterns is their nonrandomness—the presence of some rule of ordered distribution of units. It starts in the molecular realm and pervades the living structure all the way up to its harmonious total form. Yet, as I have tried to stress, the final harmony we visually admire is but the product of the rules of harmony that have governed its makings. The next diagrams were developed to depict emerging order in molecular and colloidal dimensions (63); the far left ones show a random disarray of isotropic or polar particles, while on the right, the particles assume patterns of various degrees of regularity, as in crystallization. These same principles, however, reappear

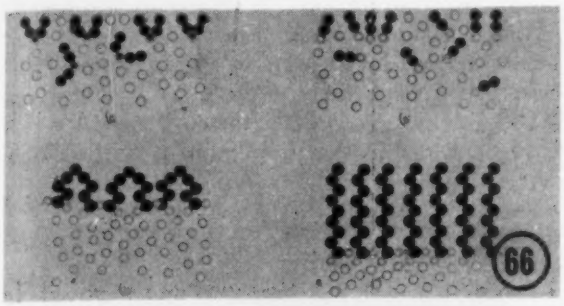


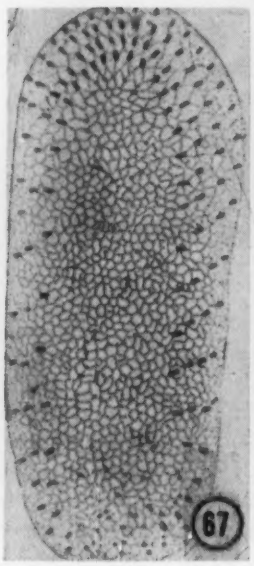
in larger dimensions as the self-ordering of systems of particles in cells, or cells in tissues, or parts in organisms, or even organisms in a group. Wherever we study such emergent order, we recognize it to be of tripartite origin, involving (i) elements with inner order, (ii) their orderly interactions, and (iii) an environment fit to sustain their ordered group behavior. There may be, after all, a common principle embracing the hexagonal stacking pattern in this virus crystal (64) shown under the electron microscope, the hexagonal array of protein fibers in muscle (60), of facets in the insect eye (37), and even of eggs on a water bug's back (65).

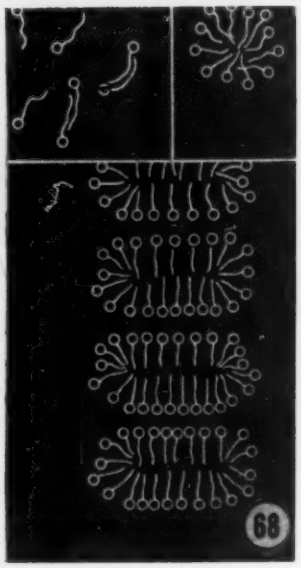


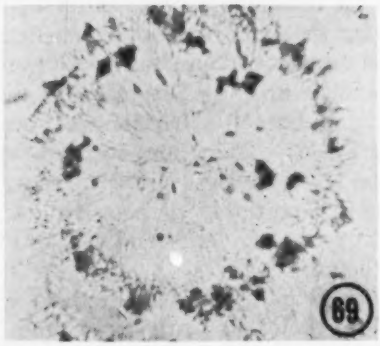


The self-sorting of polar molecules along an interface (66) may not be different in principle perhaps from the progressive order assumed by the organelles of the regeneration field of a ciliate protozoan (67), which emerges in orderly steps from an erstwhile irregular network. The molecular huddle of polar micellae, with homologous ends pointing toward center, as is seen in the formation of coacervates (68), could be a valid model of the radial agglutination of spermatozoa with tail tips in the middle and heads describing the surface of a sphere (69). In all these cases we are dealing with the ordered reactions of orderly elements to an ordered set of conditions, and the result is order. It is this rule of order that we perceive as beauty.









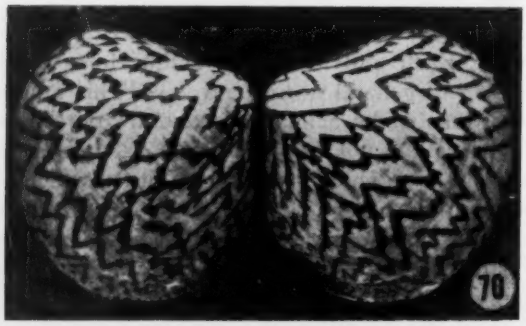
Yet, looking back over the whole series of our examples, we realize that this is order without minute precision, order within which there is scope. Therefore, let us not confound rule with fixity, order with rigor, regularity with stereotypism. Each individual is a unique form of expression of general norms and laws. This uniqueness wants to be acknowledged and appreciated. It reveals the absolute stereotype as fiction, unnatural, unorganic, nonviable if it existed. Observation of nature thus justifies our instinctive rebellion against the stereotype, against a concept of order so mechanized and rigid as to make no allowance for some degree of latitude for the individual events within it. True organic order, as we know it, sets only the general frame and pattern, leaving the precise ways of execution adjustable, and, to this extent, indeterminate. Esthetically, the principle finds expression in the superiority of handicraft, with no two objects wholly congruous, over the monotony of serial machine production. Biologically, it manifests itself in the superiority of laws of development which prescribe only the mode of procedure but leave the actual execution free to adapt itself to the exigencies of a world whose details are themselves unpredictable.

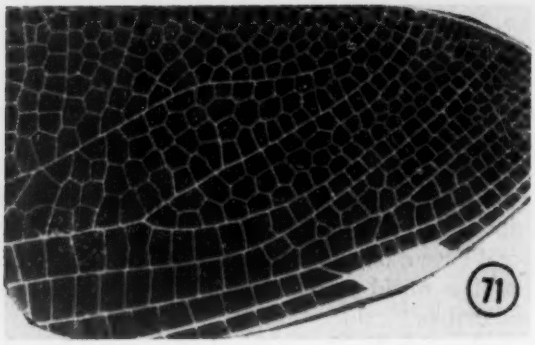
And politically, it ought to be our cue. Opposing doctrines that make so much of their advocacy or deprecation, as the case may be, of what they call the rule of order, should, first of all, make clear how tight they conceive the order to be that they are talking about.

It simply is not true that we have no choice except between the Scylla of lawless and reckless exercise of private license heading for chaos and the Charybdis of a strait jacket of absolute conformity with no leeway for exercise of responsible judgment and the freedom of decision that goes with it. Organic nature has no room for either scheme. It weeds them out as they arise—the one for its amorphousness, the other for its lack of adjustability. Life is order but order with tolerances.

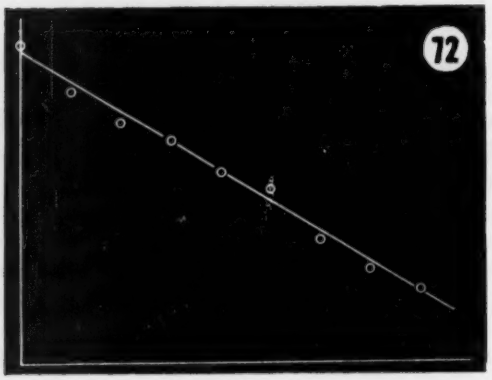
If there is any lesson in the study of organic nature, it is that there is order in the *gross* with freedom of excursion in the *small*. Our sense of beauty only confirms it, for it combines pleasure in contemplating the gross, over-all order with appreciation of pleasing variations of detail. Let

me show this once more in concrete form (70). These are two halves of the bivalve shell of a single animal. Your first impression is one of exquisite symmetry. Both patterns show, indeed, the very same character. Yet, if you try to compare the details, you promptly notice how greatly they diverge one from the other. Or take another case: this wing of the dragonfly (71) shows meshes in its

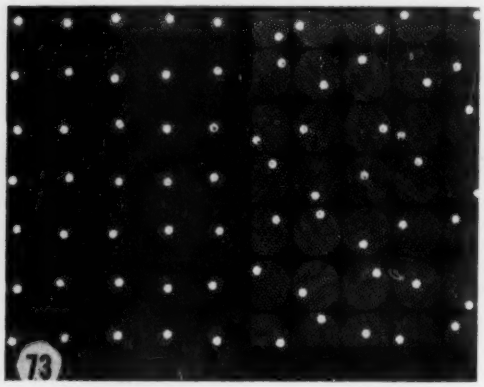




network which individually in their outlines and positions are as unique and arbitrary as the pattern of crackled enamel on a pot; only, in general, you note a gradient of density and numbers from the upper to the lower margin. Now I have subdivided this wing into nine equal horizontal strips and counted the number of meshes within each. Plotted serially, these numbers closely fit a straight line (72). This line then symbolizes the general law of distribution. But just as important as this standard course are the individual deviations of the actual values from the mean, which will be different in each individual case. It is these very differences that make for diversity of individual accomplishment within the rule; they make the individual organism unique, interesting, and, above all, viable.



Thus there is a message in the beauty of living things, a message that I should like to summarize in this last diagram (73). It represents two systems of order as two identical lattices of equidistant points defined by the centers of the stippled circles. The circles symbolize the range within which a white point inside is free to roam—a range that is much wider in the right than in the left half.



The white points mark the stations of individual items or events within the system: for instance, of atoms in a crystal, cells in a tissue, or organisms in a group. Each item can assume any position within its circle. I have let them assume random positions. Now, note that in spite of this factor of uncertainty, or, if one wishes, of individual self-expression, the pattern *as a whole* is well preserved and stands out clearly in the left half; whereas on the right, it is completely lost and obliterated. Does not this spell out for us an organic design for living? *Freedom within the law*: responsible freedom to move within an orbit as wide as, but no wider than what is compatible with the preservation of the over-all order that defines the harmony of relationships on which effective living and survival depend. To judge just what the right proportions are calls for a "sense of proportions," perhaps the golden mean, which happens to be terms and concepts borrowed from esthetics.

We may confidently confront those who claim that science holds no humanistic value with our

conclusion: beauty, as perceived by living creatures such as ourselves, is but the test and validation of the rule of order over chaos and of the tolerable degree of elemental freedom that is compatible with it.

So, harmony and life—beauty and beast—are one. The story is an old one, but it is not always told in pictures.

Illustration Credits

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Chambered Nautilus

The cover this month is a photograph of a chambered nautilus shell (cut in half). The shell of the nautilus is a striking example of the mathematical preciseness that can be found in the growth patterns and forms of living things. The shell of the nautilus has the form of a logarithmic spiral, whose equation is $r = a^{\theta}$. X-ray photographs of the nautilus shell have also shown that it is right-handed; that is, the shell spirals in a clockwise direction. The cover photograph was taken by A. M. Winchester, Stetson University, De Land, Florida.

Homeostasis, Society, and Evolution: A Critique

JULES HENRY

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ONE of the attractive features of the theory of homeostasis as a physiological principle is its *completeness*. Actually, the complete theory is made up of roughly 15 statements about the functioning of higher animal organisms. It is not clear that all who use the word *homeostasis* are aware of these dimensions when they are analogizing from the homeostasis of the body to the functioning of society.

Theory of Homeostasis

As discussed in Cannon's book (*1*), homeostasis is related to the following 15 items.

1) *The fluid matrix.* "In the main, stable states for all parts of the organism are achieved by keeping uniform the natural surroundings of these parts, their internal environment or fluid matrix" (p. 287). By fluid matrix is meant the blood and other body fluids.

2) *The margin of safety.* The human body is not "set up with a niggardly economy," but there is much "allowance for contingencies." The body in most of the important aspects of its functions has more than it needs. We could get along with one kidney, one lung, much lower blood pressure than the "normal," and so forth. The body has resources far beyond those made necessary by ordinary living.

3) *The functions of storage and elimination.* The constancy of the internal milieu of the body is maintained not only through excess of vital organs, but also through the capacity of the body to store more than it needs—for example, blood sugar—and to rid itself rapidly of excesses—for example, water or carbon dioxide (pp. 207, 290, 293).

4 *The specificity of complementary interaction.* As an example, the process whereby the organism increases its supply of oxygen during muscular work is one involving mechanisms of great variety and specificity, operating in complex ways toward a common end—that is, providing the body with the unusual quantity of oxygen required by the work and finally restoring the organism to rest. During this process, many different mechanisms are set in operation, each one of which is triggered by a preceding change. Thus, for example, the increased carbon dioxide in the bloodstream stimulates the "respiratory center" in the medulla, which results in increased vigor of respiration, and in "pumping out the extra carbon dioxide in the alveoli." "When that has continued to the extent of reducing the percentage to the normal level of calm existence, the extra stimulation of the respiratory center subsides and quiet breathing is resumed" (p. 150).

5) *Defense.* In his chapter entitled "Natural defenses of the organism," Cannon states:

> In a sense the preservation of the constancy of the fluid matrix of the body may properly be regarded as a defense against unfavorable conditions which would arise if the constancy were not preserved. And there is little doubt that the mechanisms of homeostasis belong to the general category of protective functions. But there are special reactions of the organism, nicely adapted to dangers which might arise from the presence or attack of injurious external agents. . . ."

Among such devices, Cannon mentions the various protective reflexes in the respiratory tract; the excessive salivation consequent on the placing in the mouth of some noxious substances; the vomiting reflex, and others. In connection with the system of defense, it is particularly important to take note of Cannon's phrase "*special* reactions of the organism *nicely* adapted to dangers . . . ," for here again we have the ideas of specificity and complementary interaction.

6) *The even course that involves the crucial concept of the baseline.* Many of the fundamental normalities or basic conditions of the human organism have been measured and are known: pulse and respiration rate, blood volume, blood sugar level, and so forth are known, and it has been demonstrated that the body functions in such a way as to maintain these conditions constant, or on an "even course." As Cannon says (p. 227), "In considering the homeostasis of blood sugar, oxygen supply, acid-base reactions and temperature, certain adaptive reactions were described which kept the body on an even course in spite of conditions which might have been deeply disturbing."

7) *Constancy as the necessary condition for freedom and independence.* This idea was taken over by Cannon from Bernard, whom he quotes (p. 38), "'It is the fixity of the *milieu intérieur* which is the condition of free and independent life . . . and all vital mechanisms, however varied they may be, have only one object, that of preserving constant the conditions of life in the internal environment.'"

Cannon then says (p. 302):

> The pertinent question has been asked by Barcroft, freedom for what? It is chiefly freedom for the activity of the higher levels of the nervous system and the muscles which they govern. . . . The full development and ample expression of the living organism . . . are made possible by such automatic regulation of the routine necessities that the functions of the brain which subserve intelligence and imagination, insight and manual skill, are set free for the use of these higher services.

I think it can readily be seen that such a conception of the consequences of homeostasis provides an excellent biological underpinning for any liberal democratic theory of progress and explains in part why the concept of homeostasis has captured the imaginations of some scientists. The theory, however, can also serve as a vade mecum for imperialism—namely, if you want to hold on to your empire, keep it off balance in such a way that only the motherland can maintain it in a steady state. When the outlying possessions are able to regulate themselves, they will want to throw the mother country away—that is, they will want the freedom which their own self-regulatory mechanisms now permit them to achieve.

8) *The relation between external and internal change.* As Cannon says (p. 267):

> . . . states of the *external* environment, and also responses of the organism itself to situations in the external environment, are associated with disturbance of the *internal* environment. This personal, individual climate, which we carry with us, must not greatly change if we are to continue to be effective. For constancy of the internal environment, therefore, every change in the outer world, and every considerable move in relation to the outer world, must be attended by a rectifying process in the inner world of the organism. The chief agency in this rectifying process . . . is the sympathetic division of the autonomic system.

In this connection, Cannon mentions such things as the coagulation of the blood when blood vessels are opened, the constriction of the peripheral blood vessels in the presence of cold, and the increased action of the heart in high altitudes that results from the reduction of oxygen supply. These changes in the body, it will be noted, are highly specific; they are "pin-pointed" to *particular events* in the outer world and set in motion by a particular neural agency, the sympathetic system.

9) *Automaticity.* (See also items 7 and 10.) In discussing "how the uniformity of the fluid matrix is preserved," Cannon says (p. 288): "A noteworthy prime assurance against extensive shifts in the status of the fluid matrix is the provision of sensitive automatic indicators or sentinels, the function of which is to set corrective processes in motion at the very beginning of a disturbance."

Here, indeed, is stated the essence of homeostasis: it works of itself—it is, as Cannon says, *automatic.* Crucial to physiological homeostasis also is that the mechanism is "set . . . in motion at the *very beginning* of a disturbance." On the *whole* the self-regulatory processes are set in motion before disturbance has gone too far. Sometimes, of course—for example, in gross injury or in disease—homeostasis cannot correct the disturbance of the constancy of the internal milieu, and in addition, sometimes the body can misinterpret the signals that come to it (*2*). But on the *whole* this automaticity does indeed work and does so from the beginning.

At this point it seems important to remind ourselves, particularly those of us who work in the behavioral sciences, that Cannon points out (pp. 288–289) that there are not a few cases in which we have no "clear knowledge of what the indicator is or how it works." Physiologists can see self-regulation taking place, but in some cases, even in the highly controlled field of physiology, they do not know the processes that carry it through.

10) *Resistance to change.* "If a state remains steady it does so because any tendency towards change is automatically met by increased effectiveness of the factor or factors which resist the change" (p. 299).

(11) *The presence of spiraling effects.* The faster the blood flows, as in hemorrhage, for ex-

ample, the more rapidly the blood will clot (pp. 44–45).

12) *Management of waste.* Not only does the body eliminate products it cannot use, but mechanisms are set in motion for the transportation and elimination of waste. Sometimes, as in the case of the capillaries, for example, the same mechanism carries in needed supplies and carries away waste.

13) *The preparation for struggle.* In the case of the emotions of rage and fear (pp. 227–228),

> Respiration deepens, the heart beats more rapidly, the arterial pressure rises, the blood is shifted away from the stomach and intestines to the heart and central nervous system, [and so on]. . . . The key to these marvelous transformations in the body is found in relating them to the natural accompaniments of fear and rage—running away in order to escape from danger, and attacking in order to be dominant. . . . The emotional responses just listed may reasonably be regarded as preparatory for struggle.

14) *The natural instability of the body.* Cannon says (pp. 286–288), "One of the most striking features of our bodily structure and chemical composition that may reasonably be emphasized . . . is extreme natural instability. . . . The central problem in understanding the nature of the remarkable stability of our bodies, therefore, is that of knowing how the uniformity of the fluid matrix is preserved."

Thus Cannon starts from *instability,* and sets his task as that of understanding how the body remains stable at all. It will be immediately apparent to students of the behavioral sciences that his position is at 180 degrees from the sociology that assumes social stability ("equilibrium") and sets itself the task of understanding instability.

15) *The relative isolation of the internal from the external milieu.* This conception is best expressed in the language of C. Bernard, ". . . the environment . . . is separated more and more from the outer cosmic environment, by reason of the same organic development [toward freedom]. A living body . . . is . . . independent in its advance and modality." Bernard makes it clear that the organism's capacity to regulate itself is achieved by virtue of its relative insulation from the "outer cosmic environment" as he called it. This insulation is made possible by the existence of "a limiting surface membrane, the intactness of which is essential for the integrity of *le milieu intérieur.* Disruption of this barrier between internal and external environment is incompatible with life" (*3*).

Thus homeostasis has been empirically demonstrated to be a process which, operating from a *measurable baseline* (for example, normal pulse rate, blood sugar level, and so forth), works *automatically* through a system of *specific* and intricately *complementary* mechanisms that are controlled to a considerable extent by the autonomic nervous system as a *governing system* and implemented through *a specific medium,* the so-called "fluid matrix." Homeostasis makes it possible for an organism that is essentially unstable to *maintain itself at the maximum efficiency* possible for it at a given point in its life cycle, while it slowly changes in the direction of evolution and degeneration (aging), and until it has reproduced itself and brought up its young.

When we come, then, to consider the relevance of the concept of homeostasis to society, it behooves us to ask ourselves to what extent we can empirically demonstrate that society really duplicates analogically the mechanisms on which homeostasis depends: whether indeed society has specific self-regulating mechanisms, operating automatically from a definable baseline, and which tend always to hold society to a point of maximum efficiency.

Some Extensions of the Physiological Theory

Aside from applications in physiology and medicine (*4*), the concept of homeostasis has been utilized in psychology and psychiatry (*2, 3, 5*). Interesting as these extensions may be, however, they cannot be examined in this paper because my wish is to focus on the problem of the relevance of the concept of homeostasis to society.

Cannon himself was intrigued by the possibilities of the extension by analogy of his conception to human society, and the epilogue to *The Wisdom of the Body* is entitled "Relations of biological and social homeostasis." A few quotations will give a feeling for his attitude.

> Hardly any strong tendency in a nation continues to the stage of disaster; before that extreme is reached corrective forces arise which check the tendency and they commonly prevail to such an excessive degree as themselves to cause reaction. [p. 312]

> . . . the disturbances are roughly limited, and . . . this limitation suggests . . . the early stages of social homeostasis. [p. 312]

> . . . civilized society has some of the requirements for achieving homeostasis but . . . lacks others, and because lacking them it suffers from serious and unavoidable afflictions. [pp. 312–313]

> The distribution system, *i.e.* transportation, corresponds to the fluid matrix. Money and credit, too, correspond to the fluid matrix. [p. 314]

> In the complexity of modern social interrelations the strategic control would appear to reside in the

devices for distributing goods, in commerce and the flow of money rather than in manufacture and production. [317]

The organism suggests . . . that the importance of stability warrants a specially organized control, invested by society itself with power to preserve the constancy of the fluid matrix, i.e. the processes of commerce. [p. 318]

It appears, therefore, that any wisdom which the human organism has to offer to the social organism would be based on the proviso of a population which is adjusted to reasonably assured means of subsistence which is undisturbed by large increases from either local or foreign sources. [p. 319]

Just as social stabilization would foster the stability, both physical and mental, of the members of the social organism, so likewise it would foster their higher freedom, giving them serenity and leisure, which are the primary conditions for wholesome recreation, for the discovery of a satisfactory and invigorating social *milieu* and for the discipline and enjoyment of individual aptitudes. [p. 324]

Thus in Cannon's thinking homeostasis became a plank in a political platform and a theory of social control. It would appear that, like so many theories of society that seek support in biology, and particularly in analogies with the human body, Cannon's theory tended toward conservatism; what is essentially sought is social stability and, in conformity with Bernard's earlier analysis of the conditions for stability, isolation—which, if one reads Cannon aright—becomes a parochialism free from population "increases from . . . foreign sources."

Meanwhile Cannon saw shrewdly enough that modern nations were not yet self-regulating, but he believed that as society evolved they would gradually become self-regulating. This confidence that human society is evolving in the direction of the further development of homeostatic mechanisms is carried forward by Emerson, the zoologist (*6*). Emerson was impressed by the marvelous mechanisms for internal control possessed by the social insects; for so perfectly regulated did these colonies seem that he came to consider homeostatic control in the social sphere as a goal of human evolution (*7*):

These differences in the mechanisms of biological and social heredity are sufficient to separate the social sciences from the biological sciences on fundamental and valid grounds, but we err if these differences blind us to the analogous similarities implied by the term "society." Both human and nonhuman societies exhibit social division of labor, social integration, and social homeostasis. *And there is an increase in these characteristics in the genetic evolution* of animal societies and in the *cultural evolution of the human species.* [p. 344, italics mine]

. . . if we state that there is nothing in common between the architecture of termites and man, we would be forced to coin separate terms and might fail to recognize the shared functional principles. Comparisons would be delayed. The *tendency toward increased homeostasis* would be inadequately seen, and there would be less understanding of the trends and factors of societal evolution, both in human and insect. [p. 345, italics mine]

. . . an optimal balance between conservative and creative mechanisms is one of the homeostatic controls in the organism . . . [and] there is an optimal relation between social coordination and freedom of human individuals and . . . either carried to extremes would be harmful both to the individual and to the society. [p. 345]

Progress and improved homeostasis seem to be nearly synonymous. [p. 348]

This principle [of homeostasis] not only links physiology and sociology, but indicates the direction future evolution will take. [p. 352]

It is possibly not always the theorist's task to document his conjectures, and Emerson has taken this position; to the social scientist is left the task of discovering whether increase in "social homeostasis" can indeed be demonstrated throughout the milleniums of human culture and whether an "optimal relation between social coordination and freedom" can indeed be empirically established for modern nations. Meanwhile, it is important to note that for Emerson homeostasis has become a central assumption in a liberal American theory of progress (*8*).

In the social sciences, the stage was set for use of the homeostatic analogy by the concept of *equilibrium,* which was borrowed from classical mechanics and entered sociology through the writings of Pareto (*9*), Durkheim (*10*), and Parsons (*11*). Parsons has borrowed the language of Cannon for his most recent formulations. However, influenced by Pareto, he still uses the vocabulary of mechanics also (pp. 482–483):

Theory relative to such [boundary-maintaining] systems, is directed to the analysis of the conditions under which such a constant system pattern will be maintained and conversely, the conditions under which it will be altered in determinate ways. This, we may surmise, is the fundamental basis for the assumption of our "law of inertia" of social process. [Footnote to p. 482: This conception is similar to that of homeostasis in physiology.] What the theorem does is to state the fundamental point of reference for the theoretical analysis of process in the social system. The analysis of the conditions or factors affecting motivational process is always

> stated in terms relative to this point of reference. The *problem* is always some version of the problem why, given a certain change in the relevant conditions, the constant pattern which is the point of reference is altered in a certain way or, conversely, why it fails to be altered in the face of certain alterations in the conditions. The latter question is always implicit in the problem structure, the problems of theory, that is, revolve about the conditions of maintenance and alteration of equilibria which are defined as empirically observed pattern constancies of a boundary-maintaining system. The essential point is that for there to be a theory of *change* of pattern . . . there must be an initial and a terminal pattern to be used as points of reference.

Here we have it, still somewhat in the language of Pareto but now also clearly in the frame of reference of Cannon and Bernard: the boundary, constancy, and the baseline and departure from and return to it. Thus a theory originally rooted in Newtonian physics is transformed into one inspired by contemporary physiology.

Parsons does not believe that it is necessary to explain the *maintenance* of a social system, but only the processes of deviation and control (pp. 204–205); a position that seems to me to be tautological. For if we ask: What is a "process which counteracts tendencies to change the system?" (p. 204), it seems to me that the answer must be a process that *maintains* the system. There is no such process, however, in Parsons' scheme, but only an *assumed* tendency of social systems, comparable to Newton's first law in mechanics (p. 204): ". . . the 'tendency' to maintain the interaction process is the first *law of social process* . . . [and] no *special mechanisms* are required for the explanation of the maintenance of complementary interaction-orientation. . . . This assumption . . . may be compared to the first Newtonian law of motion . . . the law of inertia. . . ."

In Parsons' theory, stability is the irreducible given (*12*), and it is deviation, its control, and the reequilibration of the system that need to be understood. Cannon, on the other hand, starts from the "extreme natural instability" of the body structure. It seems to me that one arrives at vastly different attitudes toward society depending on which one of these positions one takes with respect to it. If one assumes that society is inherently stable and orderly, then the jolts and insecurities of contemporary life with all its *disorderliness* seem endlessly unexpected and disquieting, and one struggles ceaselessly to bring about an order the exact nature of which it is difficult to discern. On the other hand, if one assumes that society is inherently unstable, then one accepts disorderliness as natural in a strict sense and attempts to live in terms of perceived patterns of conflict and instability.

Test Case

Since the value of a theory inheres in its ability to help us interpret data, let us take a body of data, and see if the theory of homeostasis applies. Since, as applied to human society, the theory should help at the most elemental as well as at the most complex level, let us start with the most elemental —a mother nursing her newborn infant (*13*).

> The mother was lying on her back in a slightly raised position when the nurse carried the baby in and laid it on the bed beside the mother. The mother took the bottle and put the nipple in the baby's mouth and said, "Every time he comes in here he is asleep." The baby moved its arms. The mother took the nipple out in five seconds. Mother rubbed baby's mouth with nipple, patted baby's buttocks and shook him vigorously. Baby moved its arms near face. Mother pulled baby's hand away from face. After two attempts the nipple was successfully inserted after 47 seconds more of the nursing period had elapsed. Then the mother said, "He is not doing anything. Can they, when they are asleep?" Observer replied, "Not very well." As baby started sucking mother said, "There he goes." Baby sucked four seconds. Mother jiggled nipple and patted baby's buttocks. Baby moved its arms and mother said, "Oh, sleepy head." Mother jiggled nipple, baby moved arms again, mother said, "Come on!" and laughed. She patted baby's back and pulled baby's arm away from its face. The mother patted baby's hair, said "Come on!" shook baby, and said, "He just doesn't want to wake up." She rolled the baby from side to side. Baby moved hands over top of nipple. Mother twirled nipple, and rolled over further on her side. Baby sucked for two seconds, made a wry face, and mother said, "Hey, wake up!" She jiggled nipple again, and said, "He's having a hard time making out." She jiggled baby's arms and said, "Come on, sleepy head!" To the observer she said, "I never see him with his eyes open, hardly." She rolled the baby from side to side, jiggled the nipple, and said, "Come on, come on!" Baby moved its arms and mother said, "You never get any down you, you sleep so much." She pulled the baby's arm, and said, "Come on!" Baby moved arm. Mother pulled nipple out . . . (Six minutes had elapsed since the beginning of the nursing period.)

It will be recalled that Cannon was able to refer a very large number of body processes to specific homeostatic mechanisms, within which there is a network of complementary triggering interrelationships. Our problem in the present case, then, would be to discover, within an empirically ascertainable homeostatic process, the specific complementary relationship among such things as: (i)

the baby's being delivered in a hospital instead of at home; (ii) feeding the baby every 4 hours for 45 minutes, as prescribed in this hospital; (iii) the mother's being on a bed (instead of on the floor, for example); (iv) use of a bottle (instead of the breast); (v) the presence of the salaried, trained nurse as a mother surrogate (instead, for example, of the mother's or the husband's sister); (vi) the mother's determination to keep the baby's hands from its face; (vii) patting the baby on the buttocks; and (viii) use of the expression *sleepyhead* and other verbalizations. To the student of culture it is, of course, obvious that what is going on here is not understandable in terms of any absolute criterion of homeostasis, but must rather be referred to a *cultural* milieu. That is to say, if the events occurring in the nursing situation are to be understood in terms of a homeostatic hypothesis, we must realize that the milieu in the present case is the particular culture and that the events must be referred to some homeostatic processes peculiar to this culture.

Let us focus on the feeding schedule, and see where such a consideration will get us.

The regulations of this hospital prescribe for neonates 45 minute feeding periods every 4 hours. The question arises *whose* homeostasis is being maintained by this procedure: the baby's? the mother's? the hospital's? American society's? or the world's? The baby would eat when hungry and sleep when sleepy if permitted to do so, for its physiological homeostasis would take care of that.

In all the protocols of neonates taken in this hospital, baby is seen to drift off to sleep repeatedly, but to be awakened and obliged to suck. Thus, in social interaction at this elemental level, the baby's own self-regulatory mechanisms are ignored. If homeostasis operates at all, it has little to do with baby's self-regulating system.

Maybe the mother is maintaining her own homeostasis; maybe something would happen to upset her even course if she did not give baby a certain amount of milk specifically during the 45-minute periods that are made to occur by the hospital every 4 hours. If this were true, it would mean that what was not natural homeostasis for baby is homeostasis in some way for mother. Hence, within this biosocial system the homeostatic mechanisms of mother and baby would then appear to be opposed—at least in part. Since most of the babies in this sample are bottle-fed, physiological homeostasis of the mothers cannot be in question. Since the baby's, on the other hand, seems to be ignored, we must search for some explanation of the behavior just described within some very general sociological analog.

For example, we might ask: When the mother feeds the baby as stipulated, of what homeostatic social system is she part? We may approach the problem, it seems to me, by asking: Why does the hospital run baby-feeding this way? When we ask this question we must change our position as observers, for we then are no longer studying the mother-baby system, but the more complex mother-hospital-baby system. That is, two things have happened: (i) we see the mother and baby as part of the larger system; and (ii) we see that the hospital has interposed *its* system—homeostatic or otherwise—between mother and baby. In an almost literal sense, it becomes a question of who is feeding whom? Is the hospital or the mother feeding the baby? And is the hospital feeding the mother or is the mother feeding the hospital—that is, keeping the hospital going by obeying its rules?

In order to study this more complex system, we must know something about its properties in order that we may know what homeostasis means when applied to it. Since a modern hospital in a large city is itself a complex social system, full understanding of the new system (mother-hospital-baby) involves us in a study of interrelationships that expand rapidly outward. Some of the factors involved in understanding the larger system follow.

1) This maternity hospital is part of a large medical center that must be run according to plan.

2) A baby in our culture is a biosocial nonentity without inherent powers or virtue. Hence it is readily subordinated to a larger "plan."

3) The hospital embodies a tradition—both general and also specifically medical—of efficiency, one important component of which is routine.

4) This hospital, like so many others, is insufficient for the needs of the surrounding population—a condition characteristic of the nation as a whole, at the present time, given the present birthrate.

5) Since babies often lose weight immediately after birth, babies are not expected to leave this hospital until they have gained back to their birth weight.

Thus, in ignoring baby's own self-regulatory mechanisms, society seems to be attempting to regulate itself, as follows. (i) Permitting the baby to indulge its own self-regulatory tendencies would upset the schedule of the medical center. (ii) If the schedule were upset, the employees'—everyone from the director to the orderlies—need for simplification of functioning would be interfered with. On the other hand, were the birthrate to decline sharply, pressure on hospital facilities would diminish, and the maintenance of rigid hospital routine might appear less urgent. In this respect,

the hospital authorities would be obeying a law of human behavior, that as anxiety diminishes rigidity decreases also. (iii) Were baby not treated as a biosocial nonentity, this would be contrary to such ancient Anglo-American precepts as "spare the rod and spoil the child," and thus, perhaps, do some violence to the ethos of our striving, thrifty folk. The present movement among more "enlightened" pediatricians away from rigid schedules thus would seem to be related to changing attitudes toward infants—toward considering them "human beings in their own right"—as much as, or perhaps more than, it is related to any new scientific knowledge of what makes a good human machine (*14*).

Now let us look at some of the things these mothers say to their babies in the hospital, as they try to feed them and to quench their thirst (*15*). The expression they utter most often is "Come on!" —for example, "Come on and suck"; "Come on and wake up"; "Come on and take some more." Next in frequency is "Wake up," or some related phrase, followed in order by utterances pertaining to speed or quantity of intake, utterances in which the mother's wishes are opposed to those of the baby, utterances pertaining to achievement, work, success of baby or mother, and finally a small group of miscellaneous utterances. Since the responses of these white (*16*) mothers are relatively uniform in this situation, I have inferred that they are determined by certain uniformities in previous experience and that they are set off by cues emanating from the hospital environment—cues such as the baby's being brought to the mother from the nursery every 4 hours, the mother's being told that the baby should not go home until it has gained back to its birth weight, the urging of the nurses, and so forth. It can be inferred, therefore, that much of what the mothers do and say to their babies is by way of reduction of anxiety—anxiety to conform to the routine of the hospital. Thus the baby's physiologically determined homeostasis is altered by way of drive reduction in—that is to say, by way of the "homeostasis" of—its mother.

The matter, however, is still more complicated, for the utterances of the mother revolve around certain values in our culture—achievement, work, dominance, quantity, and the importance of failure and success, for example. These in turn are related to the importance of an expanding industrial order. Thus in a hospital, an institution of our culture, the environment of the baby obliges the mother to shove the cultural ideals down the baby's throat. When this is done, the hospital, and American society as a whole, are enabled to go on being *what they always have been.* This circumstance might conceivably be brought analogically within the conception of homeostatic control, but whether it has any relationship to optimal function, maximum human happiness, or even to the survival of the commonwealth, is an open question.

This is an important issue when we come to consider extension of the original conception of homeostasis to scientific fields outside physiology, for the conception of homeostasis as used with respect to the body involves two ideas, "normal" state and state of maximum efficiency. That is to say, the goal (*17*) of body homeostasis is to maintain the organism in a steady state, normal state, and state of maximum efficiency all at the same time. For most states outside the body, therefore, it does not seem to me that the conception applies; for on the whole society strives to maintain itself *as it is,* and "efficiency" generally turns out to be some sort of operating constancy that does no violence to traditional motivations, however conflict-producing they may appear. I have written one book (*18*) about a tribe whose "normal" state was self-destruction, and a number of papers about another whose "normal" state was one of great tension revolving around food, one of the primary factors in physiological homeostasis (*19*).

There is certainly one aspect of Cannon's theory that can be applied to society: Who would deny that society has processes aimed at resisting change? From my present position as observer, therefore, it looks as if in the hospital just discussed, baby's inherent physiological process is a menace to the social order, and hence the hospital must do what it can to alter the baby's way of life.

Before closing this section, let us return to the original summary of the empirical findings entering into the theory of homeostasis in order to see to what further degree we may err in uncritical use of the theory. Let us consider, for example, the "baseline" (item 6). In some cases it can be ascertained within seconds that something is wrong with the body, for our instruments, or even our fingers on a pulse, tell us that the organism has departed from its normal state or baseline. How shall we determine the baseline for society? We are obliged either to accept the present state as baseline, and say, for example, that the present population represents the norm from which deviation will be considered a danger sign; that the present distribution of wealth is the norm from which deviation will be considered a danger sign; that the present regulation of affairs by the Congress, President, and Supreme Court shall be the norm; and so on. And if we brush such suppositions aside and say we obviously are not so hidebound and status-quo hungry, but that we rather think of homeostasis in

Emerson's terms—as ever-improving—we still have to ask: Where *shall* the baseline be? If we do this, we start a guessing game about the future.

Where in society can we locate the principles of automaticity and complementary interaction? It will be borne in mind that the warning signals issued by the body are on the whole specific and compelling in their force. What warning signals tell us that a society is bound for destruction; and if and when we get them, are the signals indeed compelling? Is war always "bad" in the homeostatic sense? Are our own wars indeed always "good" wars in the same sense? How do we know when to *stop* fighting? It is to be remembered that the body sets its homeostatic processes in motion at the very *beginning* of the destabilization effects. Does human society do this, or do we wait often until it is too late? Where is the mechanism that *automatically* compels us to take action against political corruption? Or, indeed, is political corruption 'bad" for the body politic in the long evolutionary run between now and the time we have achieved nearly perfect "social homeostasis," as Emerson calls it? Of course, nobody cares about evolution when it comes to political corruption; one cares only whether it helps him or harms him at the moment. When we are faced with these questions, it seems to me that if we are firm believers in some ultimate homeostasis as the goal of society all we can do is sit back and say, "It is all homeostatic in the long run."

Let us take next the problem of complementary interaction. Consider the case of a Pilagá Indian who keeps some of his food, although according to the dictates of the society he ought to give it away (*19*). If he gives all his food away he will starve; but when he keeps enough to feed himself, he is frightened because he believes that those to whom he has not given food will sorcerize him. Can we, without taking into account the great burden of anxiety and hostility the Pilagá carry with them because of these very threats of sorcery, assume that Pilagá society is a "homeostatic" one just because threats of sorcery *do* manage to get food distributed? The complementary interaction between withholding food and anxiety does not always work; and even when it does, it creates stresses in the society that are damaging to interpersonal relations. It is true that, for many social events, roughly complementary processes can be found; but we cannot speak of homeostasis if the process works one day and not the next; if it is sometimes on time and sometimes late; or if it can build society up and break it down at the same time.

For such reasons, and because I have fortunately been able to document so well the history of the Kaingáng Indians' self-destruction (*18*), I cannot agree with Norbert Wiener's guess that ". . . small, closely knit communities have a very considerable measure of homeostasis; and this, whether they are highly literate communities in a civilized country, or villages of primitive savages" (*20*). On the other hand, we are in agreement in thinking that "One of the most surprising facts about the [modern] body politic is its extreme lack of efficient homeostatic processes" (p. 185); and that with regard to "the anarchy of modern society . . . [the] optimistic feeling that there must be some way out has led to an overevaluation of the possible homeostatic elements in the community. Much as we may sympathize with these individuals, and appreciate the *emotional* dilemma in which they find themselves, we cannot attribute too much value to this type of wishful thinking" (p. 189, the italics are mine).

As far as I am concerned, the mathematician has put his finger on the dilemma: it is an emotional one; a hunger for order in an apparent chaos; and a passionate wish that there be *some* way of bringing society to an imaginary stability it has never had, where people can relax in peace.

Homeostasis and Evolution

Good homeostatic controls—ones that work automatically, in a compelling way, to bring a given entity back to a discernible baseline of maximum operating efficiency—are genetically determined where they occur in the animal world. The human body is a perfect example at the organ level; communities of social insects are good ones at the social level. But once we get outside the human body, mankind has no genetically determined means for assuring homeostasis. If he did we would find the *same* ones wherever we find man, whether on the shores of the Mississippi, on the steppes of the Soviet Union, or on a coral atoll peopled with brown folk with frizzy hair in the South Pacific.

But we do not find such uniformity. Given the need to regulate his social life, man is everywhere an improvisor; sometimes his compositions turn out well, often they are bad, and his society then limps along like that of the Pilagá or the contemporary "civilized" world, or else wipes itself out. Kaingáng is one society whose history was written during the mid-course of its self-destruction; how many societies have perished in this way before their histories could ever be written? What we have today are the *remains* of human society through the ages: those societies that have *up to date* successfully coped with the problem of self-

regulation. But who shall say that this will continue; or that it represents "efficient" adaptation, or an adaptation more efficient than what existed, let us say, two milleniums ago? Who shall say that the Solonic reforms were less "homeostatic" than those of the Democratic New Deal in the United States? The essential issue with regard to society is that man should be able to perfect his own interpersonal relations; there is no indication that he is a better hand at it today than he was at the dawn of recorded history. The evidence is lacking that human society has moved at all in the direction of the stabilization of interpersonal relations. What is not lacking is evidence that human society, by virtue of the total absence of genetically determined mechanisms for governing interpersonal relations, is *unstable*; and it is at this point, so it seems to me, that sociology and biology join hands in a common approach to the problem of the physical evolution of man.

As I see it, the crucial difference between insect societies and human ones is that whereas the former are organized to achieve homeostasis, the organization of the latter seems always to *guarantee and specifically provide for instability.* And this is the hub of the matter from the standpoint of human evolution: life stresses bring about important physiological changes in the human organism. These can become hereditary through selective processes, and only organisms that can adapt to the stresses and the ensuing changes will survive. But since human society and culture determine the nature of the stresses, and since human society is unstable, the stresses on the organism are always changing. Hence physiological adjustments are always changing, and hence biological selection is always taking place in terms of the changing stresses that are produced by the perpetual instability of human social systems. Thus we reach the conclusion that *man evolves physically in terms of a perpetually unstable social life,* as well as in terms, perhaps, of inherent tendencies of the organism itself to change.

This position may be made somewhat more explicit through the following model: Let us assume that P/R stands for a specific, relatively constant ratio of rewards to punishments in a relatively homogeneous society (*21*). This ratio of rewards to punishments acts upon the organic systems of the population in such a way as to produce a relatively stable response set *a,* in the population (*22*). This set then delivers negative feedback to maintain the configuration P/R relatively unchanged over a finite period of time. Should something happen to change the configuration to P'/R' or *B,* the population now has only *a* with which to deal with the new conditions. At this point a nonexhaustive catalog of the possible events in the system is as follows: (i) *a* changes promptly to *b,* the necessary new set, so that the system is maintained under the new conditions; (ii) *a* does not change, and thus delivers feedback that tends to change *B* back to *A*; (iii) *a* and *B* interact in such a way as to drive each other to ever wider and wider divergence. This would occur, for example, where, under one set of conditions a relatively weak attack (punishment) would elicit a relatively weak but successful self-assertion *a.* Change in circumstances now brings a heavier attack *B,* which produces not *a,* but *b,* which is submission. But *b* now provokes a still heavier attack *C,* which results in *c,* which is still greater submission. Continuation of the process forces the attacked organism to leave the field (flight or death).

Obviously the sets that we find in human society are more complex than this; they include such phenomena as tendencies to colic in infants, asthma, ulcers of the gastrointestinal tract, hypertension, and so on. All these are diseases of adaptation (*4*), the products of socially engendered stresses developing on the basis of the inherent tendency of society to instability, and hence of importance for the understanding of the evolutionary process. *The early development of colic, asthma, rheumatic heart, and so on in our children is not of medical interest alone: these diseases are phenomena of evolution.*

Summary and Conclusions

The kinship systems and obligations of nonliterate peoples, religious dogmas and hierarchies, police forces, and actuarial systems are all mechanisms of social control. They are devices whereby men, once having established their social life, seek to prevent it from falling apart. These are the empirical realities of social life at the human level, and no one would deny that human beings strive to prevent the society in which they live from becoming disorganized. It is another matter, however, to urge that processes of control are *ineluctable* in their implementation, that they tend to maintain society at the level of highest efficiency, and that the movement of mankind is toward greater and greater "social homeostasis"; for in the case of any empirical test such conditions cannot be demonstrated. Furthermore, so it seems to me, one cannot develop a cogent theory of human evolution on the hypothesis of social stability, but one can do it easily on a hypothesis of social instability.

References and Notes

1. W. Cannon, *The Wisdom of the Body* (Norton, New York, 1932). While Claude Bernard is the name with which the original statement of the basic processes of self-regulation are generally associated, it is Cannon who carried the theory to perfection and gave it its present name. See C. Bernard, *An Introduction to Experimental Medicine* (Macmillan, New York, 1927).
2. L. Kubie, *Psychosom. Med.* **10**, 15 (1948).
3. G. Engel, in *Mid-century Psychiatry*, R. Grinker, Ed. (Thomas, Springfield, Ill., 1953), p. 33.
4. H. Selye, *J. Clin. Endocrinol.* **6**, 117 (1946).
5. I. Hendrick, *Facts and Theories of Psychoanalysis* (Knopf, New York, 1939), pp. 93–94; D. Orr, *Psychoanal. Quart.* **11**, 322 (1942); G. Murphy, *Personality. A Bio-social Approach to Origins and Structure* (Harper, New York, 1947), pp. 107, 489, 739, 890; W. McCulloch, in *Cerebral Mechanisms in Behavior*, L. Jeffress, Ed. (Wiley, New York, 1951), p. 42.
6. W. Allee *et al.*, *Principles of Animal Ecology* (Saunders, Philadelphia, 1949).
7. A. Emerson, in *Structure et physiologie des sociétés animales* (Colloques internationaux du Centre National de la Recherche Scientifique XXXIX, 1952), p. 333.
8. ——— in *Goals of Economic Life*, A. D. Ward, Ed. (Harper, New York, 1953), p. 277.
9. V. Pareto, *The Mind and Society*, (Harcourt, Brace, New York, 1935), vol. 4.
10. E. Durkheim, *The Division of Labor* (Free Press, Glencoe, Ill., 1947).
11. T. Parsons, *The Social System* (Free Press, Glencoe, Ill., 1951).
12. This position has recently been critically examined by F. Nadel, *Social Forces* **31**, 265 (1953).
13. These observations are one of a series made by Joan Whitehorn Boggs in the maternity ward of a large metropolitan hospital. In the case given, the extract is from a protocol taken on the third day *post partum*. See J. Henry and J. Boggs, *Psychiatry* **15**, 261 (1952).
14. J. Henry, in *Psychosexual Development in Health and Disease*, P. Hoch and J. Zubin, Eds. (Grune and Stratton, New York, 1949), p. 91.
15. J. Henry and J. Boggs, *Psychiatry* **15**, 261 (1952).
16. The unpublished protocols of Audrey Swartz on Negro mothers show some striking differences.
17. A. Rosenblueth, N. Wiener, and J. Bigelow, *Phil. Sci.* **10**, 18 (1943).
18. J. Henry, *Jungle People* (Augustin, New York, 1941).
19. ——— *Am. Anthropol.* **51**, 187 (1951).
20. N. Wiener, *Cybernetics* (Wiley, New York, 1948).
21. "A relatively homogeneous society" is a fiction adopted for the purpose of the model. A close approximation to the fiction would be the Kaingáng Indians (*18*) or the Pilagá Indians (*19*).
22. E. Hilgard, *Theories of Learning* (Appleton-Century-Crofts, New York, 1948), p. 26; L. Thompson, *America Indigena* **11**, 235 (1951).

When one visits the laboratories of famous universities, hours are spent in looking at elaborate machines, delicate instruments, special facilities for research, etc. But nearly always I have come away disappointed, feeling that I had missed seeing that priceless thing, almost the only one that really counted, the spirit of the great teachers of such institutions in operation upon the minds and hearts of their students. . . . Seemingly they [the presidents] are interested in anything and everything that will advertise the schools. Good teaching advertises a school of course, but why does not the quality of teaching interest administrators, especially since education is the main business of the universities? There are several important reasons why it does not, by far the most important of which is that it does not make a loud and immediate noise. It takes years for the results of good teaching to make a showing, and this is an age of ballyhoo and quick results.—JAMES C. CLARK; *J. Eng. Educ.* **23**, 764 (1933).

ASSOCIATION AFFAIRS

Preview of 122nd Meeting, Atlanta, Georgia

Since the time of the preliminary announcement of the Atlanta meeting, which will be held 26–31 December [*Sci. Monthly* **81**, 51 (July 1955)], the symposia listed therein have been implemented and augmented and the sections and participating societies, in a number of instances, have had to open additional sessions for contributed papers. From such program details as the names and addresses of authors, and from the volume of advance registrations and applications for housing accommodations, it is quite apparent that this year's 122nd AAAS meeting will enjoy an excellent attendance representing all sections of the continent and abroad.

As the list of participating societies and the outline of symposia show, virtually no principal field of science will be neglected. The special program, "The crisis in science education"—for which, unprecedentedly in recent years, all AAAS sections and most of the societies have cleared the morning of 29 December—the three sessions of the International Geophysical Year, the four-part AAAS–ORINS general symposium, "Atomic energy and agriculture," the distinguished evening addresses of James R. Killian, Jr., Warren Weaver, Robert R. Williams, and Laurence M. Gould on the four successive evenings 27–30 December, the 2-day Conference on Scientific Editorial Problems, and the special report on the Geneva International Conference on the Peaceful Uses of Atomic Energy by Clarence E. Larson and Shields Warren, with Detlev W. Bronk presiding, added to an exceptional series of symposia, all promise a particularly stimulating, informative, and significant meeting.

Contributed Papers

Sessions for contributed papers are too numerous to catalog. Of the 17 participating sections, the following nine have scheduled them: C–Chemistry, D–Astronomy, E–Geology and Geography, F–Zoological Sciences, G–Botanical Sciences, I–Psychology, L–History and Philosophy of Science, Np–Pharmacy, and Q–Education.

Participating societies with sessions for contributed papers are: American Meteorological Society, American Association of Clinical Chemists, Astronomical League, National Speleological Society, American Society of Parasitologists, Herpetologists League, Society of Systematic Zoology, Ecological Society of America, National Association of Biology Teachers, American Phytopathological Society, Society for the Advancement of General Systems Theory, National Science Teachers Association, and the American Nature Study Society.

AAAS General Symposium

The AAAS and the Oak Ridge Institute of Nuclear Studies have scheduled a joint program on *Atomic Energy and Agriculture*. Parts I to IV are cosponsored by AAAS Section O–Agriculture, part I by the Ecological Society of America, parts I and II by AAAS Section G–Botanical Sciences, part II by the American Society of Plant Physiologists, Southern Section, and part III by AAAS Section F–Zoological Sciences. Arranged by a committee with C. L. Comar, principal scientist, Medical Division, Oak Ridge Institute of Nuclear Studies, as general chairman.

This first presentation to a large audience of the latest research and thinking on the applications of radioisotopes in the agricultural sciences anticipates—and to a considerable extent, complements—the related and coordinated Conference on the Use of Isotopes in Agriculture that will be held 12–14 January 1956 at East Lansing, Mich., under the sponsorship of the Council of Participating Institutions of Argonne National Laboratory.

Atomic energy and agriculture, part I, "Soil-plant relations." Tuesday, 27 Dec., 2 P.M., Exhibit Hall 1, Municipal Auditorium. Arranged by Nathan S. Hall, soil scientist, Biology Branch, Division of Biology and Medicine, U.S. Atomic Energy Commission, Washington, D.C. Robert F. Reitemeier, soil scientist, Soil and Water Conservation Research Branch, U.S. Department of Agriculture Plant Industry Station, Beltsville, Md., will preside. (i) "Uses of macronutrient isotopes in soil fertility research" by L. E. Ensminger, soil chemist, Department of Agronomy and Soils, and R. W. Pearson, soil scientist, U.S. Department of Agriculture, Alabama Polytechnic Institute, Auburn. (ii) "Solubility and plant utilization of micronutrients" by D. W. Thorne, director, Utah Agricultural Experiment Station, and H. H. Wiebe, Department of Botany, Utah State Agricultural College, Logan. (iii) "Potentialities of isotopic procedures in soil evaluation" by Maurice Fried, soil scientist, U.S. Department of Agriculture, Beltsville, Md. (iv) "The use of radioisotopes in soil physics research" by M. D. Thorne, soil scientist, U.S. Department of Agriculture, Beltsville, Md., and W. A. Raney, soil scientist, U.S. Department of Agriculture, and Mississippi State College. (v) "Role of tracers in root development investigations" by G. W. Burton, chairman, Division of Agronomy, and geneticist, Georgia Coastal Plain Experiment Station, Tifton. (vi) Presentation of John Scott award to Edgar S. McFadden, agronomist, Texas Agricultural Experiment Station, by Ernest T. Trigg, vice president, City of Philadelphia Board of Directors of City Trusts, Philadelphia, Pa.

Atomic energy and agriculture, part II, "Plant metabolism and crop improvement." Wednesday, 28 Dec., 9 A.M., Exhibit Hall 1, Municipal Auditorium. Arranged by H. B. Tukey, head, Department of Horticulture, School of Agriculture, Michigan State University. H. B. Tukey will preside. (i) "Introduction" by H. B. Tukey. (ii) "Photosynthesis" by N. E. Tolbert, senior biochemist, Biology Division, Oak Ridge National Laboratory. (iii) "Nitrogen metabolism in plants

as indicated by N^{15}" by R. M. MacVicar, dean, Graduate School, Oklahoma Agricultural and Mechanical College. (iv) "The translocation of organic nutrient in plants" by C. A. Swanson, Department of Botany, Ohio State University. (v) "Nutrient uptake, with special reference to foliar absorption" by S. H. Wittwer, Department of Horticulture, Michigan State University. (vi) "Uptake and movement of plant regulators" by J. W. Mitchell, U.S. Department of Agriculture Plant Industry Station, Beltsville, Md. (vii) "Use of radiation in plant breeding" by W. Ralph Singleton, director, Blandy Experimental Farm, University of Virginia.

Atomic energy and agriculture, part III, "Animal metabolism," Wednesday, 28 Dec., 2 P.M., Exhibit Hall 1, Municipal Auditorium. Arranged by Homer Patrick, program director, University of Tennessee-Atomic Energy Commission Agricultural Research Program. Homer Patrick will preside. (i) "Introduction" by Homer Patrick. (ii) "Micronutrient metabolism" by G. K. Davis, animal nutritionist, Department of Animal Husbandry and Nutrition, Agricultural Experiment Stations, University of Florida. (iii) "Macronutrient metabolism" by C. L. Comar, principal scientist, Medical Division, Oak Ridge Institute of Nuclear Studies. (iv) "Lactation and hormones" by J. C. Shaw, professor of dairy husbandry, Dairy Department, College of Agriculture, University of Maryland. (v) "Use of isotopes in studies of amino acid synthesis in animals" by J. A. Stekol, head, Department of Physiological Chemistry and Nutrition, Institute for Cancer Research, Philadelphia, Pa.

Atomic energy and agriculture, part IV, "Food sterilization," Thursday, 29 Dec., 2 P.M., Exhibit Hall 1, Municipal Auditorium. Arranged by B. F. Trum, lieutenant colonel, Veterinary Corps, U.S. Army. H. R. Kraybill, director and vice president of research and education, American Meat Institute, Chicago, Ill., and B. F. Trum will preside. (i) "Introduction" by H. R. Kraybill. (ii) "Radiation facilities designed to process commercial quantities of food products" by L. E. Brownell, supervisor, and J. U. Nehemias, assistant supervisor, Fission Products Laboratory, Engineering Research Institute, University of Michigan, and J. J. Bulmer, research assistant, University of Michigan. (iii) "The design of a megacurie radiation source" by Bernard Manowitz, leader, Fission Products Utilization Project, and D. J. Metz, Nuclear Engineering Department, Brookhaven National Laboratory, and R. H. Bretton, Chemical Engineering Department, Yale University. (iv) "The effect of irradiation sterilization on protein, carbohydrate, and fat with particular reference to their nutritive value" by B. C. Johnson, University of Illinois. (v) "Toxicological studies on food sterilized by ionizing radiations" by M. S. Read and H. F. Kraybill, chemistry division, Army Medical Nutrition Laboratory, Denver, Colo. (vi) "Present-day status of radiation sterilization" by B. E. Proctor, head, and S. A. Goldblith, executive officer, Department of Food Technology, Massachusetts Institute of Technology. (vii) "Feasibility of food irradiation" by R. G. H. Siu, technical director Research and Development Division, Office of the Quartermaster General, U.S. Army, Washington, D.C.

Other Symposia and Panels

B–Physics

"Radiation measurements," one session, Tuesday, 27 Dec., afternoon; arranged by J. H. Howey and J. H. Tolan. "Research progress in physics," one session, Wednesday, 28 Dec., afternoon; arranged by J. H. Howey. "Training for careers in physics," one session, Thursday, 29 Dec., afternoon; arranged by J. H. Howey.

Sigma Pi Sigma and *Alpha Epsilon Delta.* "The role of physics in premedical education," one session, Wednesday, 28 Dec., morning; arranged by D. R. McMillan.

C–Chemistry

"Patterns of biochemical and histological responses to chemical agents," two sessions, Wednesday, 28 Dec., morning and afternoon; arranged by Jules Cass. "Sedimentary kaolins along the southeastern fall line," one session, Thursday, 29 Dec., afternoon; arranged by LeRoy A. Woodward. "Radiation chemistry and related fields," two sessions, Friday, 30 Dec., morning and afternoon; arranged by Ellison H. Taylor.

American Association of Clinical Chemists. "Recent concepts in clinical chemistry," one session, Monday, 26 Dec., afternoon; arranged by Albert E. Sobel.

E–Geology and Geography

"Military Geology," two sessions, Wednesday, 28 Dec., morning and afternoon; arranged by Frank C. Whitmore, Jr.

F–Zoological Sciences

"Formation and early development of the embryo," two sessions, Tuesday, 27 Dec., morning and afternoon; arranged by R. C. von Borstel, C. B. Metz, and Albert Tyler.

Herpetologists League and *National Speleological Society.* "Distribution and speciation of cave vertebrates," one session, Tuesday, 27 Dec., afternoon; arranged by G. Nicholas and James A. Fowler.

Society of Systematic Zoology. "The systematic content of general biology courses," one session, Friday, 30 Dec., morning; arranged by Ross H. Arnett, Jr.

FG–Biological Sciences

Association of Southeastern Biologists. "The species problem," two sessions, Wednesday and Thursday, 28–29 Dec., afternoon; arranged by Ernst Mayr.

Society of General Physiologists. "Applications of serology in biological research," one session, Wednesday, 28 Dec., morning; arranged by Norman G. Anderson.

G–Botanical Sciences

"The tobacco plant," one session, Tuesday, 27 Dec., morning; arranged by Barry Commoner. "The cotton

plant," one session, Tuesday, 27 Dec., afternoon; arranged by Barry Commoner.

American Phytopathological Society. "Plant pathologists can use TV," one session, Wednesday, 28 Dec., evening; arranged by Haskell Boyter.

American Society of Plant Physiologists, Southern Section. "Implications of current physiological and biochemical research on marine algae," one session, Friday, 30 Dec., morning; arranged by Aubrey W. Naylor.

I–Psychology

"Status of military psychology," one session, Tuesday, 27 Dec., morning; arranged by Wilse B. Webb. "Learning," one session, Tuesday, 27 Dec., afternoon; arranged by Stanford C. Ericksen. "Sensory processes," one session, Wednesday, 28 Dec., morning; arranged by John F. Hahn. "Primate behavior," one session, Thursday, 29 Dec., afternoon; arranged by Arthur J. Riopelle. "Brain function," one session, Wednesday, 28 Dec., afternoon; arranged by Harlow W. Ades.

Society for Research in Child Development. "Maternal deprivation," one session, Tuesday, 27 Dec., morning; arranged by William C. Rhodes. "Role learning in children," one session, Tuesday, 27 Dec., afternoon; arranged by Walter R. Smith.

K–Social and Economic Sciences

"Contemporary patterns in southern population, migration, and urbanization," one session, Wednesday, 28 Dec., afternoon; arranged by Donald P. Ray. "Political trends in the South," one session, Thursday, 29 Dec., afternoon; arranged by Donald P. Ray.

National Academy of Economics and Political Science. "Some peaceful uses of atomic energy," one session, Thursday, 29 Dec., evening; arranged by Donald Armstrong.

L–History and Philosophy of Science

"Sociology of science," one session, Wednesday, 28 Dec., afternoon; arranged by Jane M. Oppenheimer. "Science and humanities," one session, Thursday, 29 Dec., afternoon; arranged by Raymond J. Seeger. "Creativity in science," one session, Thursday, 29 Dec., evening; arranged by Raymond J. Seeger.

Society for the Advancement of General Systems Theory. "Entropy," one session, Tuesday, 27 Dec., afternoon; arranged by Ludwig von Bertalanffy.

M–Engineering

"Automation," two sessions, Tuesday, 27 Dec., morning and afternoon; arranged by M. J. Goglia. "Socioeconomic aspects of orthopedic engineering," two sessions, Friday, 30 Dec., morning and afternoon; arranged by Eugene F. Murphy.

N–Medical Sciences

"Microbiology and medical research," four sessions, Tuesday and Wednesday, 27–28 Dec., morning and afternoon; arranged by S. E. Luria.

American Association of Hospital Consultants. "Place of experimentation in hospital administration," one session, Thursday, 29 Dec., afternoon; arranged by Jack Masur.

American Psychiatric Association and *American Physiological Society.* "Physiological bases in psychiatry," four sessions, Tuesday and Wednesday, 27–28 Dec., morning and afternoon; arranged by Harold E. Himwich.

Nd–Dentistry

"Newer knowledge of the physiology of saliva," two sessions, Wednesday, 28 Dec., morning and afternoon; arranged by J. F. Volker.

Np–Pharmacy

"Applications of nucleonics to the health professions," one session, Tuesday, 27 Dec., evening; arranged by John E. Christian. "Toxic household materials and appropriate antidotes," one session, Thursday, 29 Dec., evening; arranged by Bernard E. Conley.

P–Industrial Science

"Resource development through science," two sessions, Wednesday, 28 Dec., morning and afternoon; arranged by Earle L. Rauber.

Q–Education

"Developing leaders in science," one session, Monday, 26 Dec., morning; arranged by Paul Witty. "Education of the gifted," one session, Monday, 26 Dec., afternoon; arranged by Paul Witty. "The role of evaluation in the improvement of policies and practices in institutions of higher learning," one session, Tuesday, 27 Dec., morning; arranged by James E. Greene.

AAAS Cooperative Committee on the Teaching of Science and Mathematics. "What university and college science departments can do about their responsibility for teacher education," one session, Thursday, 29 Dec., evening; arranged by John R. Mayor.

National Association for Research in Science Teaching. "Recent research in science education," one session, Wednesday, 28 Dec., afternoon; arranged by George G. Mallinson.

National Association of Biology Teachers. "The coordination of science and education," one session, Tuesday, 27 Dec., afternoon; arranged by NABT. "Science and human resources," one session, Wednesday, 28 Dec., morning; arranged by John P. Harrold and Frances Hall.

National Science Teachers Association. 'Attracting secondary students into science," one session, Tuesday, 27 Dec., afternoon; arranged by Katherine Hertzka.

X–Science in General

American Nature Study Society. "Southern agriculture from 1913 to 1956," one session, Tuesday, 27 Dec., morning; arranged by Malvina Trussell. "The nature study idea and its contribution to the school program," one session, Tuesday, 27 Dec., afternoon; arranged by Malvina Trussell. "The appeal of the nature writer

to all age groups," one session, Thursday, 29 Dec., afternoon; arranged by Malvina Trussell.

International Geophysical Year. "The earth," one session, Tuesday, 27 Dec., morning; arranged by a committee with Joseph Kaplan and Hugh Odishaw as co-chairmen. "The atmosphere," two sessions, Wednesday and Thursday, 28–29 Dec., morning; arranged by a committee with Joseph Kaplan and Hugh Odishaw as cochairmen.

National Association of Science Writers. "Inside the Salk story," one session, Tuesday, 27 Dec., afternoon; arranged by Odom Fanning.

Conferences

Two of the three recurrent conferences at a meeting of the Association will have sessions of their own. The *Academy Conference,* representing 42 academies of science, will have a full day of sessions on 28 Dec. The *Conference on Scientific Editorial Problems* will have five concurrent sessions 28–29 Dec.: (i) "Scientific and technical writing," arranged by P. H. Flint; (ii) "Scientific and technical editing," arranged by Milton O. Lee; (iii) "Storage and retrieval of scientific and technical information," arranged by Scott Adams; (iv) "Graphic methods in the communication of scientific and technical information," by J. G. Adashko; and (v) "Publications management," by C. M. Johnson. The *Conference on Scientific Manpower* is a cosponsor of the AAAS Special Program, "The crisis in science education," that will be held 29 Dec.

Special Sessions

One of the characteristic and most important features of the annual meetings of the Association is the series of outstanding general addresses by distinguished authorities that are sponsored by organizations that meet regularly with the AAAS. These special events are joint sessions with the Association and are open to the general public of the city in which the meeting is held.

1) Society of the Sigma Xi. Tuesday, 27 Dec., 8 P.M., Dinkler Plaza Room, Hotel Dinkler Plaza. "Is there a scarcity of scientists?" by James R. Killian, Jr., president, Massachusetts Institute of Technology. Joseph W. Barker, director, Research Corporation, and president, Society of the Sigma Xi, will preside. George W. Beadle, president of the AAAS, will represent the Association.

2) AAAS Presidential Address. Wednesday, 28 Dec., 8 P.M., Sisters Chapel, Spelman College, Atlanta University. "Science and people" by Warren Weaver, vice president for natural and medical sciences, Rockefeller Foundation, and retiring president of the Association. George W. Beadle, chairman, Biology Division, California Institute of Technology, and president of the Association, will preside. Preceding the address, James V. Carmichael, president, Scripto, Incorporated, and general chairman of the Atlanta meeting, will speak briefly. Following the address there will be an informal AAAS Presidential Reception in the neighboring gymnasium.

3) Scientific Research Society of America. Thursday, 29 Dec., 8 P.M., Dinkler Plaza Room, Hotel Dinkler Plaza. "Chemistry as a supplement to agriculture in meeting world food problems" by Robert R. Williams, chairman, Williams-Waterman Fund for the Combat of Dietary Diseases, Research Corporation. Wallace R. Brode, associate director, National Bureau of Standards, and chairman, Scientific Research Society of America, will preside. Chauncey D. Leake, member of the AAAS board of directors, will represent the Association.

4) National Geographic Society. Thursday, 29 Dec., 8:30 P.M., Gymnasium, State College of Business Administration. "Atlantic's farthest shores" (illustrated) by Newman Bumstead, assistant chief, Cartographic Staff, National Geographic Society. Warren Weaver, retiring president of the AAAS, will preside.

5) Reports of the Geneva International Conference on the Peaceful Uses of Atomic Energy. Friday, 30 Dec., 4:30 P.M., Committee Room 2, Municipal Auditorium. "The physical sciences" by Clarence E. Larson, director, Oak Ridge National Laboratory. "Biological and medical sciences" by Shields Warren, director, Cancer Research Institute, New England Deaconess Hospital, Boston, Mass. Detlev W. Bronk, director, Rockefeller Institute for Medical Research, will preside.

6) United Chapters of Phi Beta Kappa. Friday, 30 Dec., 8 P.M., Room Dinkler B, Hotel Dinkler Plaza. "Science and the other humanities" by Laurence M. Gould, president, Carleton College. Goodrich C. White, president, Emory University, and recent president, United Chapters of Phi Beta Kappa, will preside. AAAS president elect Paul B. Sears will represent the Association.

Vice Presidential Addresses

Vice presidential addresses have been scheduled as follows:

C–Chemistry. Robert S. Ingols, "Chlorination of water," Tuesday, 27 Dec., evening.

D–Astronomy. Gerald M. Clemence, "Standards of time and frequency," Thursday, 29 Dec., evening.

E–Geology and Geography. Wallace W. Atwood, Jr., "International cooperation in science," Tuesday, 27 Dec., evening.

F–Zoological Sciences. J. Gordon Carlson, "Some observations on the mitotic movements of chromosomes," Thursday, 29 Dec., evening.

G–Botanical Sciences. Lawrence R. Blinks, "Flora et fauna potomacensis," Wednesday, 28 Dec., evening.

I–Psychology. S. S. Stevens, "The theory and uses of scales of sensation," Tuesday, 27 Dec., afternoon.

L–History and Philosophy of Science. Raymond J. Seeger, "Man and science," Friday, 30 Dec., afternoon.

N–Medical Sciences. S. E. Luria, "Infectious heredity and its medical applications," Wednesday, 28 Dec., afternoon.

P–Industrial Science. George L. Parkhurst, "The chemical industry and its raw materials," Wednesday, 28 Dec., noon.

Q–Education. Carter V. Good, "The role of values in educational and social research," Wednesday, 28 Dec., morning.

AAAS Business Sessions

The board of directors of the Association will meet at 9:30 A.M., Tuesday, 27 Dec., in a private suite at the Hotel Dinkler Plaza. Dates and hours of subsequent sessions of the Board of Directors during the meeting will be decided at this first session.

The council of the Association will meet Tuesday, 27 Dec., at 4 P.M., in the Rainbow Roof, Hotel Dinkler Plaza. A second session of the council is scheduled for Friday, 30 Dec., at 9 A.M., in the same room, at which time the council will take up the question of what organized science can do about the shortage of science teachers and students. All members of the council have been notified individually, and it is hoped that all can attend. Subjects to be considered by the council (in addition to the agenda prepared) usually are first brought before the board of directors through the administrative secretary. During the meeting, communications for the Board of Directors should be addressed to Dael Wolfle and left at the Hotel Dinkler Plaza mail desk.

All section chairmen and section secretaries will meet Friday, 30 Dec., at 12 noon in the Central YMCA, 145 Luckie St. NW, for luncheon and a business meeting. Dael Wolfle and Raymond L. Taylor will be co-chairmen.

Founding of a New Scientific Society

Since the inception of the AAAS, a great many scientific societies have been founded at annual meetings of the Association and this natural tendency, as research specialists in a given area become numerous enough, has not diminished in the years since World War II. The Society of Systematic Zoology, which was organized at the annual meeting of the AAAS in Chicago in 1947, and the Society for the Advancement of General Systems Theory, which was organized at the Berkeley meeting in 1954—both of which are meeting with the AAAS this year—are but two instances.

At this year's Atlanta meeting, on Friday, 30 Dec., at 1:30 P.M., in Committee Room 1 of the Municipal Auditorium, there will be an organizational meeting of a proposed Society of Marine Borer Chemists and Biologists. All interested persons are invited to attend.

RAYMOND L. TAYLOR

Associate Administrative Secretary

Association Finances

Condensed statements of Association finances for the year 1954, prepared by the auditing firm of G. P. Graham & Company, are published herewith, in order that the entire membership may be fully informed regarding the financial operations, obligations, and resources of the AAAS.

The first two statements summarize operating receipts and expenditures. The final annuity payments to the Cattell estates for *Science* were drawn from the excess of receipts over expenditures in the operating account. Total annuity and inflation clause payments amounted to $269,832.82.

The last two statements summarize the status of investment and trust funds. The value of investments and the amount of investment income both increased in 1954, thanks to sound investment policies and management, but the total endowment is still meager in comparison with the magnitude of the responsibility the Association should assume in advancing science.

HANS NUSSBAUM

Business Manager, AAAS

Washington 5, D.C.
May 26, 1955

To the Council of the
American Association for the Advancement of Science
Washington, D.C.

We have examined the balance sheet of the Operating Fund of the American Association for the Advancement of Science as at December 31, 1954, and the statement of revenue and expenditures for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying statements present fairly the financial position of the Operating Fund of the American Association for the Advancement of Science as at December 31, 1954, and the results of its operation for the year then ended.

G. P. GRAHAM & COMPANY
By G. R. Bowers

Washington 5, D.C.
May 26, 1955

To the Council of the
American Association for the Advancement of Science
Washington, D.C.

We have examined the balance sheet of the Treasurer's accounts of the American Association for the Advancement of Science as at December 31, 1954, and the statement of cash receipts and disbursements for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as are considered necessary in the circumstances.

In our opinion, the accompanying financial statements present fairly the financial position of the Treasurer's accounts of the American Association for the Advancement of Science as at December 3, 1954, and the cash receipts and disbursements for the year then ended.

G. P. GRAHAM & COMPANY
By G. R. Bowers

American Association for the Advancement of Science Operating Fund
Balance Sheet as at December 31, 1954

Assets

Current assets		
Cash in banks	$220,146.70	
Accounts receivable	16,170.11	
U.S. Treasury bills	483,856.85	
Certificates of deposit	250,000.00	$970,173.66
Other assets		
Deposit with airline		425.00
		$970,598.66

Liabilities

Current liabilities		
Accounts payable	$57,298.73	
Due to the Treasurer's account—AAAS	26,636.94	
Balance of grant—Arid Lands Symposium	6,833.48	$90,769.15
Deferred income		
Prepaid dues and fees	$218,752.58	
Prepaid journal subscriptions	50,967.71	269,720.29
Reserve fund		250,000.00
Unallocated funds		
Balance January 1, 1954	$315,459.41	
Add: Excess of revenue over expenditures	44,649.81	
Balance December 31, 1954		360,109.22
		$970,598.66

American Association for the Advancement of Science Operating Fund
Statement of Revenue and Expenditures for the Year Ended December 31, 1954

Revenue			
Dues and entrance fees			$284,466.51
Journals			
Subscriptions			
From Treasurer's accounts (Life, 50-year and emeritus members)	$ 3,339.00		
Members' special subscriptions	18,858.20		
Nonmembers' subscriptions	62,086.57	$84,283.77	
Advertising		153,513.07	
Miscellaneous sales		2,730.76	240,527.60
Publications			
Binders		$ 1,878.25	
Symposium volumes		14,990.43	16,868.68
Berkeley meeting and exhibit			43,271.88
Rental income			6,107.48
Income from investments			12,448.89
Miscellaneous			6,701.55
			$610,392.59
Expenditures			
Administrative and general expense		$ 79,508.30	
Building expense		9,232.67	
Board of directors		8,752.43	
Other committees		2,526.66	
Allowance to divisions		7,279.00	
Section expense		7,720.28	
Circularization—new members		10,117.19	
Meetings and exhibits		38,596.69	
Journals		364,954.79	
Publications		27,662.22	
Employees' retirement plan		5,101.87	
Social security		2,184.32	
Miscellaneous		339.23	
Annuity			
1954 Science annuity	$ 924.91		
Inflation allowance on annuity	842.22	1,767.13	565,742.78
Excess of revenue over expenditures			$ 44,649.81

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
TREASURER'S ACCOUNTS
BALANCE SHEET AS AT DECEMBER 31, 1954

Assets

Endowment funds			
Cash in bank		$ 3,343.29	
Advanced to Gordon Research Conferences		9,465.45	
Securities—at cost		356,359.14	$369,167.88
Building fund			
Due from Operating Fund		$ 26,636.94	
Real estate		153,297.20	179,934.14
			$549,102.02

Liabilities and Reserves

Endowment funds			
For research		$172,982.18	
For general purposes		150,776.36	
For special purposes		38,872.33	
Liabilities			
Academy grants	$ 3,253.51		
Special academy grants	275.00		
Sociology prize fund	3,000.00		
AAAS–UNESCO fellowship fund	8.50	6,537.01	$369,167.88
Building fund			179,934.14
			$549,102.02

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
TREASURER'S ACCOUNTS
STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS
FOR THE YEAR ENDED DECEMBER 31, 1954

Cash balance January 1, 1954			$ 14,305.30
Receipts			
Income from investments		$ 16,873.23	
Redemption and sale of securities		436,590.15	
Life membership fees		3,600.00	
Gifts		132.00	
Special academy grants		525.00	
Deceased emeritus life membership fees		1,400.00	459,120.38
			$473,425.68
Disbursements			
Income from investments			
Allocated to building fund	$ 632.37		
Allocated to Gordon Research Conferences	1,045.88	$ 1,678.25	
Securities purchased		419,871.05	
Newcomb Cleveland prize		1,000.00	
Academy grants		4,501.50	
Special academy grants		800.00	
Emeritus life membership fees (From Jane M. Smith fund)		1,200.00	
Fees of deceased emeritus life members (To Jane M. Smith fund)		1,400.00	
Journal subscriptions (Life, 50-year and emeritus members)		3,339.00	
Expenses		521.15	
AAAS–UNESCO fellowship fund transferred or refunded		45.00	
Westinghouse Award balance refunded		279.58	
Building fund cash transferred to operating fund		25,981.41	
Advanced to Gordon Research Conferences		9,465.45	470,082.39
Cash balance December 31, 1954			$ 3,343.29

Amendments to the AAAS Constitution

At the 1953 meeting of the Association, the Council authorized appointment of a Committee on Constitution, Bylaws, and General Operations to review the Association's constitution and bylaws and to recommend appropriate changes. The committee consists of Wallace R. Brode, chairman, Roger Adams, Meredith F. Burrill, Clarence E. Davies, and Milton O. Lee. Howard A. Meyerhoff and Dael Wolfle serve as advisers to the committee.

Amendments recommended by the committee were considered by the Board of Directors during their meeting 29–30 October. The Board approved the committee's recommendations, with a few changes and additions, and authorized their submission to the Council at the annual meeting of 1955.

The constitution requires that proposed amendments be published in substance in *Science* and *The Scientific Monthly* at least a month before the Council meeting at which they are to be considered. Accordingly, the more important of the proposed amendments to the constitution are described in the following section. The next section lists several additional changes that are being recommended to clarify intent, remove ambiguities, or improve current practices.

Constitutional Changes

Article IV. A quorum now consists of 20 members, and the signatures of 20 members are required to call a special meeting of the Council. In both cases it is recommended that the number be increased to 30.

Ordinarily each Council member has one vote, but in a few cases a member represents two or more affiliated societies, and the number of votes to which such members are entitled has not been clear. It is recommended that each member have only one vote.

The president presides over Council meetings. If the president is absent, the constitution provides for the election of a chairman by the Council. It is recommended that the president elect serve in the absence of the president.

Article VI. A section committee now includes representatives from societies affiliated with that section and other Council members whose own scientific interests lie in the field of the section. Thus, some affiliated societies, such as state academies of science, may one year be represented in one section committee and the next year in another. It is recommended that representatives of societies that are not affiliated with a section that has a section committee not be made members of a section committee. If adopted, this change will mean that a society may be affiliated with one or more AAAS sections, that its representatives will serve as members of the section committees of such sections, but that the representatives will not be assigned to other section committees. To provide greater flexibility and to permit overlap of membership on section committees, it is recommended that the prohibition against serving on more than one such committee be abolished.

Article VIII. Affiliated societies have one or two representatives in the Council, depending upon the number of their members who are fellows of the AAAS. State academies of science have for some years been an exception to this rule, for regardless of size they have only one Council representative. It is recommended that this arrangement be continued and that it be specified in the constitution.

In order to make formal provision within the Association structure for such agencies as the Gordon Research Conferences, it is recommended that a new section 4 of article VIII be adopted to establish a class of "participating organizations." Participating organizations are defined as ones whose activities are planned and directed in close association with those of the AAAS. To acquire the status of a "participating organization" will require approval of both the Board of Directors and the Council. Such organizations will be given representation in the Council as determined by the Board of Directors and the Council.

Article XII. The present amendment procedure is ambiguous, names the Board of Directors as the only agency with authority to initiate amendments, and does not provide any means whereby the Council can amend the constitution over the objection of the Board of Directors. It is recommended that a vote of the Council or a petition signed by 30 members of the Council also be authorized as means of proposing constitutional amendments. It is further recommended that the Council be given authority to adopt an amendment that is not approved by the Board. To do so, under the proposed amendment, would require a majority vote of the Council at one meeting to place the proposed amendment on the agenda of a subsequent annual meeting, and for adoption would require a two-thirds vote of the Council at that subsequent annual meeting.

Changes of Detail

The Board of Directors recommends that the title of the administrative secretary be changed to executive officer, and that the corresponding change of wording be made throughout the constitution and bylaws.

Article II. It is recommended that only individual members—not institutions and organizations—be eligible for election as fellows.

It is recommended that the word *his* be inserted just before the last word of sections 5(a) and 5(b).

In section 5(c) it is recommended that institutions or organizations—as well as individuals—be given the right to establish and name sustaining memberships and to name the first incumbent of such memberships. It is further recommended that the Board be given discretion as to the continuation of a sustaining membership after the death of an incumbent.

Article III. It is recommended that the term of office of the president elect and of the vice presidents be defined as 1 year.

It is recommended that the titles of assistants to the administrative secretary not be stated in the constitution but be left to the discretion of the Board of Directors,

and that the Board be authorized to designate which assistants shall be classed as administrative officers of the Association.

Article V. To avoid possible ambiguity, it is recommended that there be a slight rearrangement of the material of section 2. It is recommended that a quorum of the Board of Directors be changed from five members to six voting members. It is further recommended that the term of office of each member continue until his successor shall have signified in writing his acceptance of office.

Article VI. In the event of the death or resignation of an elected member of a section committee, it is recommended that a successor be elected by the section committee instead of by the Board of Directors.

Article XI. In order to avoid confusion with other meanings of the term *trust funds,* it is recommended that this classification of the Association's funds be renamed *endowment, trust, and gift funds.*

Article XII. It is recommended that a new article XII be adopted, specifying that Roberts' rules of order, except when inconsistent with the constitution or bylaws, shall govern meetings of the Council.

It is recommended that the current article XII be renumbered XIII and that, in addition to the changes in amendment procedure already described, the language specifying that proposed amendments be published in *Science* and *The Scientific Monthly* be replaced by the more generally stated requirement that amendments be officially published.

All articles. It is recommended that all articles be given short titles, such as *purpose, membership, officers,* and so forth.

Procedure

In advance of the 1955 Council meeting, members of the Council will be mailed copies of the constitution, and also of the bylaws, with the recommended changes indicated in detail. The Council will vote on these matters at the 1955 meeting. If the changes are approved, the revised constitution and bylaws will be published in *Science* and *The Scientific Monthly* early in 1956.

DAEL WOLFLE

Administrative Secretary

This statement is also being published in Science *(25 November).*

BOOK REVIEWS

The Facts of Life. C. D. Darlington. Macmillan, New York, 1955. 467 pp. Illus. + plates. $7.

This is science fiction at its best. The literary style is comparable to the best fiction, and the scientific content is what good science fiction should be—an extension of a few recent discoveries into the realm of tantalizing possibilities.

The main theme centers around cytology and genetics, the field in which the author himself gained distinction. Leaning heavily on Johann Lange's examination of the criminal records of ten monozygotic twins, Darlington asserts that man's temperaments, his understanding of truth and beauty, his "susceptibility to every disease, infectious or non-infectious, that flesh is heir to," as well as many physical characteristics, are "limited and prescribed in the fertilized egg."

From this follow diverse implications on various subjects: Marx's views of history, Freud's theory of the unconscious, racial segregation, and the vows of celibacy that are taken, according to the text, by those among the "two or three in every hundred individuals in whom the embers of passion glow with such a faint heat that the consequences of bringing them to a flame will not repay the effort." Felons cannot be reformed, since their variance is genetic and must be dealt with by "painless extinction, segregation, and the prevention of birth." Incompatible marriages cannot be remedied but must be dissolved.

The first half of the book, before the Lange twins are mentioned, is concerned with a historical introduction to cytogenetics. A long, all-inclusive, and involved argument indicates deterministic philosophies from Lucretius to T. H. Morgan. This tends to become pedantic, but a generous sprinkling of unfamiliar anecdotes and *bon mots* adroitly used make it thoroughly good reading.

Those who buy the book assuming that the title intimates discussions in the style of Kinsey will find substantiation in Chapters 15 and 16, where even a "diagram of love" is to be found. The author's ingenious wit, moreover, makes these chapters infinitely better reading than the Kinsey report. Grades of sexual potency are proved to be genetic and are classified not in man but in bulls because, unlike man, "bulls do not boast."

The assertions in this book are dogmatic, and there is little indication of the controversial nature of many of the facts, not to mention the conclusions and implications. To take only one example, a widespread phenomenon familiar to working geneticists is the appearance of phenocopies, when the environment simulates closely the action of the genotype. This phenomenon, although highly pertinent to the main argument of the book, is nowhere discussed.

My copy was undated except for "April 1952" under the preface. It would therefore be difficult to use it as a scientific reference.

HAIG P. PAPAZIAN

Department of Plant Science, Yale University

Man on Earth. Jacquetta Hawkes. Cressent, London, 1954. 21s.

It is gratifying to discover a book, such as *Man on Earth,* that discusses anthropological data in terms meaningful to the layman but without sacrifice of scientific rigor. The overspecialization frequently found in present-day science requires such extensive preparations that a barrier is introduced to the efforts of a scientist who attempts to broaden his knowledge in fields foreign to his specialty. Without a concept of the interrelationship of the scientific specialties and in turn their perspective to our social order, science becomes meaningless technology comparable to a symphony orchestra with no conductor.

With an understanding strengthened by training in the fields of both archeology and anthropology and by emotions matured by family responsibilities, Jacquetta Hawkes traces the emergence of man from the earliest evidences of life. Her exposition contains a warmth and tenderness that is rare in scientific writing.

Her view of human history as the development of consciousness led by some force of design is in contradiction to the orthodox view. This divergence can reasonably be attributed to the warmth of her view. This viewpoint, although it is developed carefully, is not a salient feature of the work and does not become an important issue.

Separate chapters are devoted to tracing the development of the backbone and the warm blood stream. In these chapters, animal life existing long before the emergence of man is described. The next chapter, "Culture," discusses much of the evolution of *Homo sapiens* from the animal life previously developed through the Java man and the Peking man to our present cultures.

A chapter on the development of the brain discusses some of the basic trends in evolution that give distinction to man in the animal world. Two chapters follow in which the roles of civilization and intellect are described. In the concluding chapter, "A myth for the future," the lessons of the book are applied to the problems confronting today's society.

In this way, the subject matter is presented logically and lucidly. After developing the salient points of anthropology, the author reveals a philosophy correlating these anthropological data with present-day social questions. She considers that ". . . [the] enormous part of the energy and ingenuity of industrial activity . . . [that] goes into making it possible for more human beings to be alive at one time . . . promises in time to become catastrophic." In reference to our growing populations, she adds, "Great numbers are a positive evil in the morality of consciousness." She feels that we must gain control of these great numbers, although she would be fearful of an anarchy that ". . . might lead to stampedes."

Another sinister force that threatens to produce the deliberate corruption of consciousness, she claims, is the use of mass communications. "This evil desecration of mind, rendering men mental lepers unfit for their duty to apprehend the truth of the world so far as they are able, must rank as the greatest sin in the morality of consciousness."

Hawkes warns against concluding that evolution is a procession "leading to some promised goal, some glorious apotheosis in future time. Every moment in the process has its own incomparable value." Although there is no goal to which we are progressing, she says that we now know enough of the past to comprehend a significance in human evolution "that is the bringing into being, the heightening, and the intensifying of our consciousness through creative experience at every level of existence."

Man on Earth is stimulating reading, encouraging a broadened view to the nonanthropologist. The author's keen perception allows her to pursue a scholarly topic that is timely and vital.

D. J. Lovell

Electronics Corporation of America

The Equatorie of the Planetis. Edited from Peterhouse MS.75.I (a manuscript treatise ascribed to Chaucer), Derek J. Price, Ed. Linguistic analysis by R. M. Wilson. Cambridge Univ. Press, New York–London, 1955. xvi + 214 pp. Illus. + plates. $10.

The major part of this book consists of a facsimile reprinting, a transcription, and a translation into modern English of a 14th-century manuscript describing the construction and working of the "equatorie," a device for calculating planetary positions. This is followed by a discussion of the manuscript itself, the tables of astronomical positions, and the history of devices for computing the position of the planets from antiquity until the end of the 14th century.

Of interest primarily to historians of science and of English literature, rather than to scientists, this work is certain to attract attention because of the possibility explored by the editor that the original manuscript may be in the autograph of the great poet Geoffrey Chaucer, who wrote a famous treatise on the astrolabe for the use of his son. It is also valuable because there are in print very few Middle English scientific texts, particularly astronomical texts, and because new sources of information on methods of computing planetary positions are always welcome.

D. J. Price's discussion of the evidence that the manuscript may have been written by Chaucer is more exciting than most detective stories, and he has made use of many intriguing photographic techniques to restore erased words and to compare what may be Chaucer's signature on this manuscript and on a document in the Public Record Office in England. But whether or not the manuscript treatise itself may be properly ascribed to Chaucer, the publication of it, with critical and explanatory notes by Price, will be welcomed by all historians of science.

I. Bernard Cohen

Department of the History of Science,
Harvard University

Pomp and Pestilence. Infectious disease, its origins and conquest. Ronald Hare. Philosophical Library, New York, 1955. 224 pp. $5.75.

Historical accounts of the great plagues and pestilences stimulate the morbid interests of everyone. Ronald Hare's book, although it contains its full share of pandemics, is more than a catalog of tragedy. It describes briefly various human parasites from viruses to tapeworms in a style that is designed for the general reader rather than the specialist. After a short review of the principles of parasitology and epidemiology, the author considers the difficult, if not insoluble, problem of the evolutionary history of the various parasites of man. He then describes some of the pestilences of antiquity and recent times. After a consideration of the development of the germ theory of disease, he discusses public health measures, active immunization, and chemotherapy that together have resulted in the control or elimination of so many diseases. The book closes with a discussion of the present role of infectious disease in the control of population in regions that are underdeveloped.

The treatment is as factual as is possible in the history of medicine, and sensationalism is avoided. Understatement appears, as in a discussion of the Plague of Justinian, "Procopius states that several millions of millions died, but it is doubtful whether the total population was quite so high." A remarkable statement appears in a discussion of the typhus epidemic that afflicted Ireland from 1845 to 1850. "There can be little doubt that typhus has much to do with the anglophobia which still affects many of the citizens of the U.S.A." This sounds unrealistic even to the descendant of an Orangeman, although it may salve the English conscience.

The significance of the title is baffling in spite of the obvious pun and the author's weakness for alliteration. A remarkable statement on the dust cover apparently cannot be blamed on the author because it does not appear in the text, "and then there was the cholera [*sic*] epidemic in Naples in 1943, miraculously halted by DDT." This book is not intended for the serious student of the history of medicine but it may be read with interest by almost anyone else.

MARK H. ADAMS
Department of Microbiology, New York University

Plants without Flowers. Harold Bastin. Philosophical Library, New York, 1955. xi + 146 pp. Illus. + plates. $6.

This is a nontechnical survey of the portion of the plant kingdom below the level of the seed plants. The book begins with a chapter on evolution from the most primitive algae to the most advanced pteridophytes and then devotes one or more chapters to each of the major groups of plants. Common names are used for most of the species discussed, but the Latin names for them are given in a glossary at the end of the book. Practically all the plants described in detail are found in Great Britain, and it is obvious that the author has a firsthand field acquaintance with the seaweeds, mosses, liverworts, ferns, horsetails, and lycopods that he discusses. On the other hand, the author seems to have a secondhand knowledge of microscopic structures involved in reproduction of the plants he discusses, and this has resulted in a number of erroneous statements in the portions dealing with this phase in the book. This is especially the case with the chapter on the algae.

The quality of the illustrations is also uneven. The 20 plates of photographs are excellent. Contrasted with this the line drawings are exceedingly crude, and several of them are inaccurate. An extreme example is Fig. C on page 97, which purports to be a sporangium of a fern.

GILBERT M. SMITH
Department of Biology, Stanford University

Apes, Angels, and Victorians. William Irvine. McGraw-Hill, New York, 1955. 399 pp. Illus. $5.

"The question is this," said Disraeli, 5 years after the publication of *Origin of Species,* "Is man an ape or an angel? My Lord, I am on the side of the angels." With this prefatory statement, William Irvine brings once more to our attention the dramatic story of Darwin, Huxley, and the battle for evolution. This story has been often told but perhaps never better than in the present volume. In part, the superiority of Irvine's work can be traced to his use of hitherto unpublished source material. We learn, for example (p. 61), that Darwin was advised by his father to conceal his religious doubts from his bride-to-be in order to spare her needless suffering. (He took this advice—although the truth eventually did out.) In addition, the author recognizes the importance and makes use of Douglas Hubble's psychiatric study (1943) of Darwin's character.

The excellence of Irvine's book does not depend on new revelations, however. In terms of quantity, the great bulk of the facts in the case were long ago revealed in the various standard two-volume "Life and Letters" that serve as capstones to so many eminent Victorian lives. The facts are old, but they are worth retelling, especially for a new generation; without such occasional repetitions, the truth is in danger of being lost under the rapidly accumulating sediments of later, but no more significant, events.

Besides the principal characters in the Darwin drama, Irvine introduces us to a strong supporting cast: Carlyle, Gladstone, and Matthew Arnold, among others. With very few lapses, the author documents his statements, skillfully weaving in the authenticated words of the actors themselves. When the author obtrudes his own interpretations one feels that they are usually justified by the facts. Perhaps one *caveat* needs to be made: it seemed to me that there was a slight air of condescension toward Darwin, "the neurotic"—an air that is blessedly missing from Hubble's own discussion of the great biologist.

The book reads well, and rapidly for the first two-

thirds of its length. In the latter part, however, the story drags somewhat; not because it is any the less well written, but rather because the great battles are over, and now we must witness the plethora of ovations and honors given to Darwin and Huxley. One might ask for judicious and drastic surgery in this part, for, as Huxley said of Hume, "success and wealth are rarely interesting." But perhaps the author is right in adhering to his style to the very end; the result is less dramatic, but perhaps it is truer to life.

GARRETT HARDIN
University of California, Santa Barbara College

Human Physiology. W. B. Youmans. Macmillan, New York, 1954. xiv + 481 pp. Illus. $6.

It has long been my opinion that a thorough understanding of the fundamental principles of biological science is essential to the intelligent layman if he is to develop a sound philosophy of life. Furthermore, if biological principles are to be effective in the development of a philosophy of life, it is desirable that these principles be understood in their relationship to man himself; in other words, it is desirable that the layman have his introduction to biology through the field of human physiology. For the implementation of such a program, it is essential that we have not only intelligent and inspired teachers of biology but also interesting and scientifically accurate textbooks.

Youmans' recent textbook, *Human Physiology,* serves as an admirable introduction to the subject. It is as brief as is consistent with an adequate presentation of the material. It is written in a clear concise style and in a way that I believe would hold the interest of beginning students. The opening chapters, in which he deals with the characteristics of the cell, the composition of protoplasm, and general biochemistry principles, as well as some of the chief considerations in regard to cellular biology, are admirably designed to introduce the student to the field of general biology. The order of presentation is in general conventional but always interesting and authoritative. The book should be valuable in increasing the popularity and effectiveness of introductory courses in human physiology.

FRED A. HITCHCOCK
Department of Physiology, Ohio State University

Bird Recognition 3. The third of four volumes treating British birds from pigeons through swallows. James Fisher. Penguin Books, Baltimore, Md., 1955. 159 pp. Illus. 85¢.

In contrast to comparable American books whose emphasis is on identification, Fisher's book emphasizes the whole life of the bird. This is illustrated, for example, by the ingenious graphic representation in the British Isles of the annual cycle of behavior, breeding, and movements for each species. Under each category Fisher also lists valuable published studies of some aspect of the life of the species, which point to the vistas of bird study beyond identification. Most of these references will offer new facets and really interesting aspects to American amateurs. They point out also that many of the best studies are not written in English. In contrast, the bibliographies in American journals are conspicuous for their lack of citation of "foreign" papers.

It is convenient for our readers that Fisher has used the American Check List sequence. My only objection is that the illustrations are with a few exceptions neither diagrams for identification nor portraits. They are dramatized and formalized and do not equal the interest in the personality of birds expressed in the text. This volume and the preceding volumes recommend themselves highly to any birder or field naturalist.

WILLIAM H. DRURY, JR.
Department of Biology, Harvard University

Cells and Societies. John Tyler Bonner. Princeton Univ. Press, Princeton, N.J., 1955. 234 pp. Illus. + plates. $4.50.

John Tyler Bonner has attacked a matrix of fundamental and very difficult problems in his stimulating book *Cells and Societies.* The title might well have been *Societies and Cell.* This order of terms would then correspond to the order with which Bonner develops the complex themes and presents evidence on the common denominators, "The sameness of living things," and the great variabilities with which living organisms feed, reproduce, and coordinate their activities. Bonner systematically develops the thesis that there is an ordered continuity of basic biological processes extending over the vast range of living organisms from societies of howling monkeys, fur seals, red deer, beavers, army ants, and termites to the single cell.

The principal concepts of *Cells and Societies* are functional. In an interesting and readable style, Bonner raises questions and answers them with the available but not always adequate evidence. The questions are generally related to how animals and plants adapt and adjust themselves to their environments. Societies are described in terms of adjustments related to functions. Similarly feeding, breathing, circulation, excretion, and reproduction are meticulously described in a conceptual system of adaptations and adjustments.

Bonner by his refreshing approach and somewhat novel organization of his subject has avoided some of the frustrating dichotomies and conceptual barriers that prevent a systematic representation of organisms and their activities. He is not disturbed by the "society" or "group" versus the "individual" or the "organism" versus "environment" dichotomies. His theme flows from one type of primate or mammalian society to colonial hyoids, to cell colonies, to single cells. He describes animal and then plant functions while maintaining a unity of concepts and terminologies. He does not perceive the vast chasms seen by some authorities as separating the inorganic from the organic, the plants

from the animals, and even the "lower" primates from the primate *Homo sapiens*. Herein lies the great strength of *Cells and Societies* for the nonauthoritative-bound and un-pedantic reader. Some experts may be disturbed by the lack of rigid systematic delimitations or constantly reiterated exceptions and reservations. However, it is inferred that the book was not written for experts. It seems to have been written for intelligent and curious nonspecialists who want to know interesting facts and principles about the world of living organisms. If the specialist can relax his constrictive skepticisms, he too may profit from reading *Cells and Societies*. The textbook-satiated students especially, both in the biological and social sciences, should enjoy and benefit from reading this stimulating book with its broad perspective.

Certainly Bonner would not argue that he has "solved" all the fundamental problems of continuity, variability, and adaptivity of living organisms. He has, however, sketched them in a new perspective and with a rare relativistic synthesis.

C. R. CARPENTER

Department of Psychology,
Pennsylvania State University

Plane Trigonometry. C. R. Wylie, Jr. McGraw-Hill, New York–London, 1955. viii + 381 pp. Illus. $4.

The outstanding feature of C. R. Wylie's new book *Plane Trigonometry* is unusually strong emphasis on the theoretical aspects of trigonometry and on related concepts and methods from higher mathematics, mechanics, and physics. While generally there is provision for purely computational and skill-producing work, this is relegated to a comparatively minor position.

First, the idea of *function is* stressed at the outset and is emphasized throughout the book. This is done by introductory material on functions, by unusually thorough developments of coordinates and graphs, and by other methods. Then there are many problems of a theoretical nature, many involving literal quantities, many requiring the derivation of formulas related to configurations, some relating to higher mathematics, and some requiring proofs. Also basic concepts from higher mathematics are introduced. Examples of these are odd and even functions, $\lim_{x \to 0} \frac{\sin x}{x}$ and other limits, summation of series, infinite series including those for $\sin x$, $\cos x$, and e, hyperbolic functions, and Euler's equations. Also worthy of note are the problems that require the solution of complicated equations, some involving algebraic and transcendental functions.

A considerable number of concepts and problems from mechanics and physics are considered. For example an analysis of $a \sin (bx - c)$ brings out that a indicates magnitude or loudness, b periodicity, and c position or phase. Vectors are stressed; they are applied to elementary problems concerning equilibrium of forces, velocities, relative velocities of airplane to wind and ground, and angular velocities. These practical problems indicate usefulness and will arouse interest.

It should be emphasized that Wylie's book takes up all the topics ordinarily treated together with a considerable number of formal problems and problems on heights and distances. His discussions are excellent. Motivational remarks are followed by appropriately complete expositions and excellent illustrative examples. The problem lists should enable a teacher to select material for students of various grades of ability. Perhaps, however, the book is best adapted to the superior class of students.

LYMAN M. KELLS

Department of Mathematics, U. S. Naval Academy

School Facilities for Science Instruction. John S. Richardson, Ed. National Science Teachers Assoc., Washington, D.C., 1954. viii + 266 pp. Illus. $5.50.

Sponsored jointly by the National Science Teachers Association and the U.S. Office of Education, a project was started in 1950 to prepare a publication on science-teaching facilities. This book is the complete report of that project. It is an interpretation in practical terms of the facilities necessary for science education, primarily done to meet the needs of science teachers, school administrators, and all those engaged in planning and teaching.

Although most of the chapters are devoted to high-school facilities, such as those for chemistry, physics, biological science, and general science there is a chapter that deals with the facilities needed for the education of science teachers. The appendix includes a list of suggested equipment and supplies, both general and special, and the trade sources for equipment.

Studies in Mathematics and Mechanics. Presented to Richard von Mises by friends, colleagues, and pupils. Academic Press, New York, 1954. ix + 353 pp. Illus. $9.

On the occasion of his 70th birthday, on 19 April 1953, these studies were presented to Richard von Mises of Harvard University, who had made many valuable contributions to various parts of applied mathematics and mechanics and had stimulated many other scientists working in these fields. Although von Mises was quite vigorous at that time, he was taken ill in May and passed away on 14 July 1953. The present volume was then published in its original form.

A short preface is signed by G. Birkhoff, G. Kuerti, and G Szegö. An introduction by Philipp Frank describes the type of philosophy of science that was basic for the work of von Mises. Then there follows an impressive bibliography containing 143 contributions of von Mises to science and philosophy and, moreover, six publications concerning the poet Rainer Maria Rilke. The scientific bibliography includes seven books on the theory of water wheels, on technical hydrodynamics, on the theory of flight, on probability and statistics, and on positivism; some of them had several editions and were translated into other languages. Besides, von Mises edited a famous work on differential and integral equa-

tions of mechanics and physics (with Philipp Frank) and *Advances in Applied Mechanics* (with Theodore von Kármán).

The 42 studies collected in the present volume show the wide range of the scientific interest of von Mises. There are nine papers on algebra, number theory, and geometry, nine articles on analysis, ten studies on theoretical mechanics, six on applied mechanics, and finally eight on probability and statistics. The names of many famous scientists in these fields are represented here and, moreover, the fact that 18 of these authors live in foreign countries is significant for the international appreciation of von Mises' work and personality.

ARTHUR ROSENTHAL
Department of Mathematics, Purdue University

Astronomy. Textbook for university and college students. Robert H. Baker. Van Nostrand, New York–London, ed. 6, 1955. viii + 528 pp. Illus. $5.50.

Astronomy, sixth edition, by R. H. Baker, is a revised version of a well-known elementary astronomy textbook. Several rewritten chapters reflect the spectacular advances that have taken place in various branches of astronomy during the 5 years since the fifth edition appeared. These chapters include treatments of the division of long-period Cepheids into classical and type II, accurate color-magnitude arrays for galactic and globular clusters with a discussion of their significance in theories of stellar evolution, observations that have led to the recognition of spiral arms in our galaxy, and radio astronomy as a new tool.

Several sections in the fifth edition have been abbreviated or eliminated to make way for the new material without lengthening the book. Among these are early theories of planetary motion, old ideas on evolution of the solar system, and some material on eclipsing binaries. The entire former section on navigation wisely has been eliminated.

The book begins with a treatment of the celestial sphere, coordinate systems, and the effects of the observer's latitude. Following this is a chapter on the earth, its properties, rotation, and revolution. Next is a discussion of time, followed by a chapter on light and telescopes. Successive chapters deal with the moon, eclipses, the solar system (three chapters), and the sun. A chapter on distances, motions, spectra, and luminosities of stars introduces the subject of stellar astronomy. Then come chapters on variable stars, binary stars, astrophysics, star clusters, the interstellar medium, the galactic system, and finally extragalactic astronomy.

Two criticisms are worth mentioning. The final chapter of 28 pages is entirely inadequate for its subject. A bibliography of important papers on specific topics would be helpful to the serious student.

This textbook provides a factual, accurate treatment of elementary astronomy. It uses no mathematics beyond high-school algebra and is well suited to a beginning college course.

ALBERT P. LINNELL
Amherst College Observatory

Sir Isaac Newton. E. N. daC. Andrade. Collins, London; Macmillan, New York, 1954. 140 pp. Illus. $1.75.

A description of the life of Isaac Newton is given in this book, in language that young readers can understand. Beginning with a chapter about science before the time of Newton, as a basis for understanding what Newton did and why it was important in the development of scientific thinking, Andrade describes Newton's life, his experiments, discoveries, achievements, and the scope of his activity. He gives a word-picture of the personality of ". . . this extraordinary man, of the world yet not of the world; supreme in the exact sciences but a mystic at heart; high minded and petty; modest and overbearing; suspicious, sensitive and shrinking, but a good man of affairs; arousing admiration, respect and reverence, but no warm human affection. A man who mixed freely with other men . . . but always a man withdrawn, guarding, in the ultimate, his own secrets as to what he believed and what he was above all seeking; a man revealing great mysteries of nature's machinery but reticent about much he profoundly pondered. . . ."

Introductory Applied Physics. Norman C. Harris and Edwin M. Hemmerling. McGraw-Hill, New York, 1955. viii + 729 pp. Illus. $6.75.

The growing interest in physics courses for technical institutes and trade schools has developed a demand for specialized textbooks. Few such physics books have been published. Hence, it seems likely that *Introductory Applied Physics* will find a welcome reception.

If portions of this book are chosen with discrimination by experienced teachers, its stated objective of providing a groundwork leading to a better understanding of technical problems encountered in industry may well be achieved. But the length of the book and the large fraction of material on industrial applications are likely to limit its usefulness to certain specialized institutions with curriculums that are particularly adapted to courses in applied physics.

The format and presswork are unusually good. Students will find the review summaries and the illustrative problems very helpful. A considerable amount of space is devoted to excellently selected halftone engravings of industrial devices and machinery.The number of questions and problems at the end of each chapter is not large. Many of the very limited number of questions are merely of the memory type, requiring no reasoning or analysis by the student. Most of the problems are easily solved and of a routine variety. They are carefully written to apply to relatively familiar industrial situations.

In their endeavors to make the material palatable, the authors have chosen to utilize some definitions and terminology that will be highly objectionable to physics teachers. For example, *mass* and *weight* are used interchangeably throughout the book; units of *mass* and *force* are very badly mixed up; many basic definitions are incorrectly stated ("density is the weight (mass) of a unit

volume of a substance," "stress is defined as the force producing a deformation"); formulas are sometimes dimensionally incorrect ($f = m$, $PE = mh$, J is used both for Joule's equivalent and for joules). A superficial reading of the book indicated at least 50 such loose and incorrect statements.

The book has an excellent introductory chapter and a chapter on precision measurement. But it is a shock to find the authors recommending consideration only of the number of *decimal places* in numerical problems rather than the number of *significant figures*. No consideration is given throughout the book to the correct usage of significant figures in problems.

The amount of "modern physics" in this book is limited almost entirely to a well-written and illustrated concluding chapter.

MARSH W. WHITE

Department of Physics,
Pennsylvania State University

Minnesota's Rocks and Waters. A geological story. George M. Schwartz and George A. Thiel. Univ. of Minnesota Press, Minneapolis, 1954. xviii + 366 pp. Illus. $4.

Based on a premise that too little has been done with regard to educating the people of Minnesota to appreciate and understand the natural resources of their state, Schwartz and Thiel have written, in nontechnical language, this geologic story of Minnesota. Part I, "The story of rocks," is both a historical and a present-day account of the land, resources, rocks, and minerals of the state. This part also serves as a foundation for the appreciation and enjoyment of the account of the major geologic features of this diversified state. These features are described in detail in part II, "Geological excursions through Minnesota." The book includes a list of the minerals of the state and a glossary.

Ferns of Tennessee. With the fern allies excluded. Jesse M. Shaver. Bureau of Publications, George Peabody College for Teachers, Nashville, Tenn., 1954. xvii + 502 pp. Illus. + plates. $6.

A good many states now have local fern floras, among the best being those of Minnesota, Wisconsin, Michigan, Louisiana, Georgia, New Jersey, and New Mexico, which are useful works but of limited general interest. The most recent book, *Ferns of Tennessee*, is of a different class in excellence. It is not only the longest, most elaborate, and most beautiful but also one of the most scientific and accurate. Fifty-six species are treated, with about nine pages of text and four or five illustrations for each species. These full descriptions are mostly drawn from living material The illustrations include line drawings, photographs of herbarium specimens and of living plants in their natural habitats, and outline maps showing the distribution.

Most of this book was previously published in a long series of articles in the *Journal of the Tennessee Academy of Sciences*, beginning in 1942. As Shaver tells us in his preface, reprints were made as they appeared, repaged so as to form a continuous book. It might be feared that such handling would lead to some inequality in the treatment, but this is not the case; the author selected a suitable format and followed it consistently throughout the years. The only deviation from the original plan was the omission of the fern allies (*Isoëtes, Lycopodium, Selaginella,* and *Equisetum*), an omission caused by an unfortunate accident that has prevented Shaver from completing his work.

It is impossible to note here all of Shaver's interesting comments and observations on natural habitats, geographic distribution, morphology, and nomenclature. Most noteworthy perhaps are the extensive treatments of the variations of walking fern, southern maidenhair, royal fern, ebony spleenwort, marginal shield fern, and fragile fern. An interesting detail is the quotation of reports concerning the root system of bracken (*Pteridium aquilinum*). One main rootstock 89 feet long was measured, and another 67 feet long had a single lateral branch 200 feet long (including long laterals). These figures, obviously the result of much hard labor in excavation, show that many "colonies" of bracken are undoubtedly all single plants connected underground by branching rootstocks.

The value of this fine book is not only to residents of Tennessee nor even to students of ferns in general but to all who are interested in the wild plants of the eastern United States.

C. V. MORTON

Smithsonian Institution

The Encyclopedia of Child Care and Guidance. Sidonie Matsner Gruenberg, Ed. Doubleday, Garden City, N.Y., 1954. 1016 pp. Illus. $7.50.

This encyclopedia of current experience and thinking in child care and guidance, written for those whose life or work involves responsibilities for children and their development, is divided into two main sections.

Part I, "Ready references to child care and guidance," has more than 1000 alphabetically arranged entries (534 pp.); a listing of agencies and organizations grouped according to such topics as health, handicapped children, family welfare, vocational guidance, marriage counseling, and parent education. A bibliography of books and pamphlets completes this first section.

Part II, "Basic aspects of child development," consists of 30 chapters written in nontechnical language by specialists in their chosen fields. Some of the chapters and their authors are "What we know about the development of healthy personalities in children," by Benjamin Spock; "What children inherit," by Benjamin C. Gruenberg; "How children begin to learn," by Herbert G. Birch; "How children grow," by Nancy Bayley; "Early steps in growing up," by James L. Hymes, Jr.; "Adoles-

ence: on the way to maturity," by Mary Fisher Langmuir; "How to handle children's fears," by Helen Ross; "Juvenile delinquency is everybody's business," by Richard Clendenen; "Character and spiritual values," by Arthur L. Swift, Jr.; and "Married love and parent love," by David R. Mace.

Educators Guide to Free Films. Mary Foley Horkheimer and John W. Diffor. Educators Progress Service, Randolph, Wis., 1954. xiv + 566 pp. Paper, $6.

Those who use visual education as a supplementary part of their teaching program will be interested in this 14th edition of *Educators Guide to Free Films.* An annotated schedule of films and their sources, this guide has listings in the fields of applied and fine arts, health education, social studies (such as geography, conservation, and history), and the sciences (physics, chemistry, biology, and general). Under these headings the available films are further divided into 33 special areas. Titles of 2982 are listed; all new ones are marked with an asterisk. This encyclopedic film reference is an up-to-date record of material currently available.

Mammals. A guide to familiar American species. Herbert S. Zim and Donald F. Hoffmeister. Simon and Schuster, New York, 1955. 160 pp. Illus. Paper, $1; cloth, $1.95.

Sponsored by the Wildlife Management Institute, the Golden Nature Guides are a series of books published by Simon and Schuster. *Mammals* is the seventh title in the series. It is a collection of pictures and descriptions of 218 animals as arranged and captioned by Herbert Zim, University of Illinois, and Donald F. Hoffmeister, curator of the Natural History Museum of the same place.

The illustrations are full-color paintings, and the entire book serves as a guide to recognition of American species of mammals. Nature lovers and children, in particular, will enjoy and derive value from the book. An interesting addendum to the collection is a list of the scientific names for the species illustrated and a guide to various museums and zoos.

Plant Life in Malaya. R. E. Holttum. Longmans, Green, London–New York, 1954. viii + 254 pp. Illus. $3.

An account of the rich and diverse plant life in Malaya is given in this book. It covers roots and stems, bamboo, ginger, orchids, yams, and other tubers, flowers and hybrids, fruits and seeds, bananas, grasses, fern, climbing plants, parasites and saprophytes. A list of the botanical equivalent of Malaya and English plant names is appended.

Dictionary of European History. William S. Roeder, Ed. Philosophical Library, New York, 1954. vii + 316 pp. $6.

This book contains concise information about most of the events (political, social, economic, and cultural) and prominent individuals from A.D. 500 to the present time. Although it deals primarily with Europe, references to colonies, the Western Hemisphere, and both the Near and Far East are included. The volume is particularly designed to aid in understanding the Europe of today. Consequently, history of the leading contemporary powers is stressed.

Your Career in Physics. Philip Pollack. Dutton, New York, 1955. 127 pp. Illus. + plates. $2.75.

With physicists already in short supply and falling enrollments in secondary-school physics courses a matter of widespread national concern, there is a real need for an outstanding career guidance book in the area of physics. Philip Pollack's account of the opportunities and the future of physics is highly readable and will undoubtedly be one of the more popular volumes in the guidance counselor's library.

However, I must admit to a sense of disappointment in the way this book meets the challenge of the present urgent situation. With the exception of a few brief sections, notably in a final short chapter entitled "Physics invades other fields," the volume tends to emphasize the gadgets that are the indirect results of science and that, lamentably, often are used to define career areas that can live and grow only by a refusal to be so defined. It is often argued that the high-school student will not respond to the lure of exploration, discovery, and understanding that are both the motivation and satisfaction of the research scientist; and indeed that these qualities are not always foremost or even essential for a useful and rewarding career in physics or its derivatives. Nevertheless, if the word *curiosity* appeared once in the entire text, it certainly escaped my attention.

The criticisms of the shortcomings of this volume are directed not so much at the author, who after all has exerted his efforts in our behalf, as at the profession that, for unfathomable reasons, provided him with so little exciting material. Physics may "design the modern world" as Pollack suggests, but little of modern physics is discussed. Thoughtful physicists may also ponder why, in the appendix listing colleges and universities that offer major courses in physics, 62 are named for aeronautical engineering while only seven are identified as providing undergraduate courses in nuclear physics.

In summary, Pollack and other authors and publishers should be urged to revisit physics.

JOHN S. COLEMAN
Division of Physical Sciences, National Academy of Sciences–National Research Council

Books Reviewed in SCIENCE

7 October

Analytical Cytology, R. C. Mellors, Ed. (Blakiston-McGraw-Hill). Reviewed by W. L. Doyle.

Studies of Biosynthesis of Escherichia coli, R. B. Roberts *et al.* (Carnegie Institution). Reviewed by W. W. Umbreit.

Mechanisms of Microbial Pathogenicity, J. W. Howie and A. J. O'Hea, Eds. (Cambridge Univ. Press). Reviewed by C. M. MacLeod.

Philosophy and Analysis, M. Macdonald, Ed. (Philosophical Library). Reviewed by R. J. Seeger.

Linearized Theory of Steady High-Speed Flow, G. N. Ward (Cambridge Univ. Press). Reviewed by J. D. Cole.

Science and the Human Imagination, M. B. Hesse (Philosophical Library). Reviewed by G. Hardin.

The Chemistry of Petroleum Hydrocarbons, B. T. Brooks *et al.,* Eds. (Reinhold). Reviewed by B. J. Mair.

14 October

Operations Research for Management, J. F. McCloskey and F. N. Trefethen, Eds. (Johns Hopkins Press). Reviewed by J. B. Lathrop.

The Chemistry of Lipids of Biochemical Significance, J. A. Lovern (Methuen; Wiley). Reviewed by J. Folch-Pi.

A History of Dermatology in Philadelphia, R. Friedman (Froben). Reviewed by L. H. Warren.

Transactions of the Symposium on Computing, Mechanics, and Partial Differential Equations, F. E. Grubbs, F. J. Murray, J. J. Stoker, Eds. (Interscience). Reviewed by M. Rees.

21 October

Aluminum Paint and Powder, J. D. Edwards and R. I. Wray (Reinhold). Reviewed by F. C. Frary.

Machine Translation of Languages, W. N. Locke and A. D. Booth, Eds. (Wiley; Chapman & Hall). Reviewed by J. Rothstein.

The Technology of Solvents and Plasticizers, A. K. Doolittle (Wiley; Chapman & Hall). Reviewed by H. F. Mark.

Electroplating Engineering Handbook, A. K. Graham and H. L. Pinkerton, Eds. (Reinhold). Reviewed by L. S. Foster.

28 October

Crust of the Earth, Arie Poldervaart, Ed. (Geological Soc. of America). Reviewed by E. Willard Berry.

Adrenal Cortex, Elaine P. Ralli, Ed. (Josiah Macy, Jr. Foundation). Reviewed by James Salter and Charles H. Best.

Industrial Inorganic Analysis, Roland S. Young (Wiley; Chapman & Hall). Reviewed by Laurence S. Foster.

Précis d'Ecologie Animale, F. S. Bodenheimer (Payot). Reviewed by Joel W. Hedgpeth.

Solvents Manual, compiled by C. Marsden, Ed. (Cleaver-Hume; Elsevier). Reviewed by H. F. Mark.

Chemistry of Carbon Compounds, vol. III, pt. A, E. H. Rodd, Ed. (Elsevier). Reviewed by Roy G. Bossert.

New Books

The Luminescence of Biological Systems. Proceedings of the Conference on Luminescence, 28 March–2 April, 1954. Frank H. Johnson, Ed. American Assoc. for the Adancement of Science, Washington, D.C., 1955. 452 pp. $7; AAAS member, $6.

Lectures on Functions of a Complex Variable. Wilfred Kaplan, Ed. Univ. of Michigan, Ann Arbor, 1955. 435 pp. $10.

Linear Feedback Analysis. J. G. Thomason. McGraw-Hill, New York; Pergamon, London, 1955. 355 pp. $8.50.

Microbiology. Ernest Gray. Philosophical Library, New York, 1955. 175 pp. $3.75.

Science News. No. 36. A. W. Haslett, Ed. Penguin Books, Baltimore Md., 1955. 128 pp. $0.65.

The Chemistry and Fertility of Sea Waters. H. W. Harvey. Cambridge Univ. Press, London, 1955. 224 pp. $5.50.

Soil Warming by Electricity. R. H. Coombes. Philosophical Library, New York, 1955. 116 pp. $4.75.

Plant Ecology. Reviews of research. Arid Zone Research, VI. UNESCO, Paris, 1955. 377 pp. $7.

Climates in Miniature. A study of micro-climate and environment. T. Bedford Franklin. Philosophical Library, New York, 1955. 137 pp. $3.75.

Chemical Engineering Cost Estimation. Robert S. Aries and Robert D. Newton. Mc-Graw-Hill, New York, 1955. 263 pp. $6.

Experimental Psychology. A series of broadcast talks on recent research. B. A. Farrell, Ed. Philosophical Library, New York, 1955. 66 pp. $2.75.

Forestry and Related Research in North America. Frank H. Kaufert and William H. Cummings, Soc. of American Foresters, Washington, D. C., 1955. 280 pp. $5.

The Josiah Macy, Jr. Foundation, 1930–1955. A review of activities. The Foundation, New York, 1955. 174 pp.

Laplace Transforms for Electrical Engineers. B. J. Starkey. Iliffe, London, 1954; Philosophical Library, New York, 1955. 279 pp. $10.

Dictionary of Legal Terms, Spanish-English and English-Spanish. Louis A. Robb. Wiley, New York; Chapman & Hall, London, 1955. 228 pp. $8.

The Negro in Science. Julius H. Taylor, Ed. Morgan State College Press, Baltimore, Md., 1955. 192 pp. $3.50.

Advances in Experimental Caries Research. A symposium. Reidar F. Sognnaes, Ed. American Assoc. for the Advancement of Science, Washington, 1955. 236 pp. $6.75; AAAS member, $5.75.

Midwest and Its Children. The psychological ecology of an American town. Roger G. Barker and Herbert F. Wright. Row, Peterson, Evanston, Ill., 1954. 532 pp. $7.50.

Cardiovascular-Renal Problems. vol. 1, *Clinical Pathologic Conferences of Cook County Hospital.* Hans Popper and Daniel S. Kushner, Eds. Blakiston—McGraw-Hill, New York, 1954. 325 pp. $5.

Proceedings of the UNESCO Symposium on Typhoons, 9–12 November 1954, Tokyo. Japanese National Commission for UNESCO, Tokyo, 1955. 257 pp.

Human Physiology. F. R. Winton and L. E. Bayliss. Little, Brown, Boston, ed. 4, 1955. 616 pp. $8.

The Story of Man and the Stars. Patrick Moore. Norton, New York, 1955. 246 pp. $3.95.

Our Backward Children. Karl F. Heiser. Norton, New York, 1955. 240 pp. $3.75.

Logique et dynamique du peuplement végétal. Phytogeographie, phytosociologie, biosystématique, applications agronomiques. M. Guinochet. Masson, Paris, 1955. 140 pp.

Radio Astronomy. International Monogr. on Radio. J. L. Pawsey and R. N. Bracewell. Oxford Univ. Press, New York–London, 1955. 361 pp. $8.80.

Antimetabolites and Cancer. A symposium. Cornelius P. Rhoads, Ed. American Assoc. for the Advancement of Science, Washington, D. C., 1955. 312 pp. $5.75; AAAS member, $5.

Determination of Organic Structures by Physical Methods. E. A. Braude and F. C. Nachod, Eds. Academic, New York, 1955. 810 pp. $15.

Horner's Dictionary of Terms Used in the Theory and Practice of Mechanical Engineering. Staton Abbey, compiler. Philosophical Library, New York, ed. 7, 1955. 121, 417 pp. $6.50.

A Catalogue of the American Hesperiidae indicating the Classification and Nomenclature adopted in the British Museum. pt. IV. *Hesperiinae* and *Megathyminae.* W. H. Evans. The Museum, London, 1955. 499 pp. £4.

Catalysis. vol. III, *Hydrogenation and Dehydrogenation.* Paul H. Emmett, Ed. Reinhold, New York; Chapman & Hall, London, 1955. 504 pp. $12.

Experimental Electronics for the Beginner. Lewis G. Blevins and Leonard R. Crow. Universal Scientific Co., Vincennes, Ind., 1955. $3.50.

The Metallurgy of Zirconium. Benjamin Lustman and Frank Kerze, Jr., Eds. McGraw-Hill, New York, 1955. 776 pp. $10.

Montaña y los Origenes del Movimento Social y Cientifico de Mexico. Jose Joaquin Izquierdo. Ediciones Ciencia, Mexico, 1955. 442 pp.

Operationism. A. Cornelius Benjamin. Thomas, Springfield, Ill., 1955. 154 pp. $4.

Universe, Unlimited. A new concept of atomic structure with a unification hypothesis. Hugh Sloss. Vantage, New York, 1955. 197 pp. $2.75.

Science and Christian Belief. C. A. Coulson. Univ. of North Carolina, Chapel Hill, 1955. 127 pp. $2.50.

Production of Heavy Water. National Nuclear Energy Series Division III, vol. 4F. James O. Maloney, George F. Quinn, Harold S. Ray, Maxwell L. Eidinoff, George G. Joris, Ellison Taylor, Hugh S. Taylor, and Harold C. Urey. McGraw-Hill, New York, 1955. 394 pp. $5.25.

Principles of Nuclear Reactor Engineering. Samuel Glasstone. Van Nostrand, New York, 1955. 861 pp. $7.95.

A History of Dermatology in Philadelphia, including a Biography of Louis A. Duhring, Father of Dermatology in Philadelphia. Reuben Friedman. Froben, Fort Pierce Beach, Fla., 1955. 556 pp. $10.

Electro-Technology. Basic theory and circuit calculations for electrical engineers. M. G. Say. Philosophical Library, New York, 1955. 167 pp. $6.

Einführung in die Medizinische Psychologie. Fur Mediziner und Psychologen. Georg Destunis. De Gruyter, Berlin, 1955. 218 pp. DM. 22.

Quantum Mechanics. International Ser. in Pure and Applied Physics. Leonard I. Schiff. McGraw-Hill, New York–London, ed. 2, 1955. 417 pp. $6.50.

The Life and Work of Sigmund Freud. Years of Maturity, 1901–1919. vol. 2. Ernest Jones. Basic Books, New York, 1955. 512 pp. $6.75.

Legal Medicine, Pathology and Toxicology. Thomas A. Gonzales *et al.* Appleton-Century-Crofts, New York, ed. 2, 1954. 1349 pp.

The History of the Telescope. Henry C. King. Sky, Cambridge, Mass.; Griffin, London, 1955. 456 pp. $12.50.

A Million Years of Human Progress. Ira D. Cardiff. Pageant Press, New York, rev. ed., 1955. 146 pp. $2.50.

Introduction to Electronic Analogue Computers. C. A. A. Wass. McGraw-Hill, New York; Pergamon, London, 1955. 237 pp. $6.50.

An Introduction to the Principles of Chemistry. L. H. Cragg and R. P. Graham. Rinehart, New York, rev. ed. 1955. 740 pp. $6.50.

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History of the Cold War. Kenneth Ingram. Philosophical Library, New York, 1955. 239 pp. $5.

Genetics Notes. James F. Crow. Burgess, Minneapolis 15, ed. 2, 1955. 124 pp. $2.50.

Spider, Egg, and Microcosm. Eugene Kinkead. Knopf, New York, 1955. 243 pp. $4.

Birds and Men. American birds in science, art, literature, and conservation, 1800–1900. Robert Henry Welker. Belknap Press of Harvard Univ. Press, Cambridge, Mass. 1955. 230 pp. $5.75.

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Textbook of Occupational Therapy with Chief Reference to Psychological Medicine. Eamon N. M. O'Sullivan. Philosophical Library, New York, 1955. 319 pp. $10.

Static and Dynamic Electron Optics. An account of focusing in lens, deflector and accelerator. Cambridge Monogr. on Mechanics and Applied Mathematics. P. A. Sturrock. Cambridge Univ. Press, London, 1955. 240 pp. $5.50.

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General Chemistry Workbook. Conway Pierce and R. Nelson Smith. Freeman, San Francisco, 1955. 249 pp. $1.65.

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Inflatable Lamp

Krene plastic has been used to make a new inflatable lamp that hangs from the ceiling and can be raised or lowered to any desired height. The complete lamp kit contains an inflatable shade, bulb assembly, suspension and light cords, ceiling hook, and instructions. The light bulbs are mounted in a wire frame that fits into the center hole of the doughnut-shaped shade; pressure from the shade holds the bulb assembly in place. The inflated shade is about 20 in. in diameter and 10 in. high. (Carradan Associates, Dept. SM, 154 E. Erie St., Chicago 11, Ill.)

Moisture-Vapor Barrier

Visqueen is a plastic film that can be used for moisture-vapor barriers under concrete slabs, on the ground in crawl spaces, over sub-flooring, and on the warm side of exterior walls. The film is supplied in thicknesses from 0.002 to 0.02 in. in rolls up to 16 ft wide. The film, which is made of Bakelite polyethylene, is light in weight, tear-resistant, chemically inert, and flexible in low temperatures. (Visking Corp., Dept. SM, P.O. Box 1410, Terre Haute, Ind.)

Electromagnet

A new laboratory electromagnet with two fixed coils has poles adjustable for an air gap up to 4.3 in. A variety of cylindrical, conic, or specially shaped pole caps is available. Field flux densities up to 28,600 gauss can be obtained. (Special Products Div., Dept. SM, Varian Associates, 611 Hansen Way, Palo Alto, Calif.)

Storage Cabinet

Glass tubing can be kept clean and dust free with a new storage cabinet that contains removable compartments sealed against dust by felt pads mounted on the inner surfaces of both the door and the back. The inside dimensions of the cabinet are 12 by 12 by 50 in. The removable compartments are available in various sizes. (Bethlehem Apparatus Co., Inc., Dept. SM, Front and Depot Streets, Hellertown, Pa.)

Double-Capillary Manometer

A new single-rod double-capillary manometer is available in four models: two, with different neck lengths, that are adaptable to any Warburg apparatus; one a differential manometer; and the other a Summerson constant-volume differential manometer. Both capillaries are open to the bottom, one is open at the top to atmospheric pressure, and the other is open at the top to the reaction flask and three-way stopcock. One 30-cm scale graduated in millimeters serves for both capillaries. (Bronwill Scientific, Inc., Dept. SM, 131 Gould St., Rochester 7, N.Y.)

Laboratory Pen

Tech-Pen is a ball point pen that writes on glass, metal, porcelain, paper, plastic, cloth, leather, and many other surfaces. The ink, which is available in seven colors, is resistant to alcohol, acids, alkalis, washing, weathering, rubbing, and temperatures up to 500°C, but it can be removed with common solvents when necessary. (Palo Laboratory Supplies, Inc., Dept. SM, 81 Reade St., New York 7.)

Variable Inductors

Miniature variable inductors with a variation range of 2:1 are available in 10 standard values from 56 mh to 1.8 mh. Operating temperature range is from −50 to +100°C; Q factor is approximately 200; ratings are 2.5 watts and 400 v. The inductors are 1⅛ in. long and ¾ in. in diameter. (Levinthal Electronic Products, Inc., Dept. SM, 2607 Fair Oaks Ave., Redwood City, Calif.)

Dry-Fly Spray

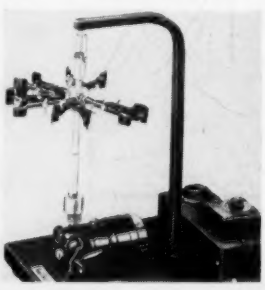
Dry-fly fishermen can give their lures a long-lasting water-resistant coating by means of a new spray available in a 2 oz aerosol dispenser. The spray dries after one back cast and leaves no oily ring. (Hank Roberts, Inc., Dept. SM, P.O. Box 171, Boulder, Colo.)

Distilled Water Heater

Hot distilled water can be kept on tap by means of a new water heater. The water is maintained at any temperature predetermined by the thermostat setting. The tank, which is made of tinned copper, has a capacity of 1½ gal. The unit is equipped with pilot light, 650-watt heating element, cord, switch, and dial type thermometer with a range of 30 to 240°F. (Barnstead Still and Sterilizer Co., Dept. SM, 256 Lanesville Terr., Forest Hills, Boston 31, Mass.)

Laboratory Shaker

Designed to carry a large variety of laboratory glassware, a new multipurpose shaker has a timer, clamps that are adjustable in two ways, and a rheostat for controlling the speed of agitation. (Palo Laboratory Supplies, Inc., Dept. SM, 81 Reade St., New York 7.)



SUGGESTIONS FOR CONTRIBUTORS

These suggestions, if followed by authors, will serve to expedite the reviewing and processing of articles and to reduce appreciably the costs of processing and printing.

Every article, letter, or book review is accepted with the understanding that it has not been published or accepted for publication elsewhere. (Occasionally an important article is reprinted from another periodical, usually one not readily available to readers of *The Scientific Monthly,* but this is always done by special arrangement with the author.)

An article should receive a thorough review before submission, if possible by someone other than the author.

The manuscript should be submitted in duplicate. For the first copy, use a good grade of 8.5- by 11-in. nontransparent paper. *All copy, including quotations, footnotes, tables, literature references, and legends for figures, should be double-spaced.* Leave margins of at least 1.5 in. at the sides and at the top and bottom.

Pages that are heavily corrected should be retyped. Do not insert corrections and additions along the margin; the printer works with the typescript mounted in a frame that exposes only a few lines at a time.

Illustrations. A brief legend should be provided for every diagram and photograph. It should *not* be incorporated in the figure. All legends are set in type by the printer and, hence, should be gathered together on a separate sheet.

On the margin or back of each illustration, write in pencil the number of the figure, name of the author, and abbreviated title of the article. All illustrations should be packed carefully with cardboard to avoid damage in mailing. Cracks and marks made by paper clips or pressure of writing ruin photographs for reproduction.

Line drawings should be made with India ink on heavy white drawing paper or blue tracing cloth. A good size for a drawing is twice that desired for the printed figure, with all lettering and line thicknesses similarly enlarged. One-column-width illustrations are reproduced 3 in. wide; full-page-width illustrations, 6⅛ in. wide.

Diagrams containing little detail should be planned so that the printed figure can be made one column wide or less. For presenting apparatus, particularly if it is complicated, a line drawing is usually better than a photograph.

If a graph is drawn on coordinate paper, the paper must be blue lined. Lines that are to be reproduced should be ruled over in black and made thinner than the lines of the curves and those of the frame. For detailed information on the preparation of graphs, see *Science* **120,** 5A (17 Sept. 1954).

Photographs should have a glossy finish. For satisfactory reproduction, a print must be unblurred and must show sharp contrast between light and dark areas.

Tables. Each table should be typed on a separate sheet and should be provided with a title. Tables should be numbered consecutively with Arabic numerals.

References and notes. The only footnotes are to be those appended to tables or to the title of an article that has no references or other notes. All other explanatory notes, including acknowledgments and authorization for publication, and literature references are to be numbered consecutively and placed at the end of the article, under the heading "References and Notes," as is shown in the following example. All numbered references and notes are to be keyed into the text.

References and Notes

1. This article is based on a paper given in the symposium, *Species That Feed Mankind,* AAAS meeting, Boston, Mass., 27 Dec. 1953. The studies described were supported by a grant from ..... Acknowledgment is due to John Doe and Helen Blank for assistance in conducting the experiments.
2. W. C. Allee, *Science* **97,** 517 (1943).
3. The two sets of observations represent .....
4. A. K. Goodwon, *An Introduction to Ethics* (Myer Press, New York, ed. 2, 1949), p. 124.
5. This dimensional theory is more fully described in .....

Science and Technology

(From the month's news releases; publication here does not constitute endorsement.)

Portable Lantern

Propane in a disposable steel cylinder is the fuel for a new portable gas lantern designed for use by hunters and campers. The lantern provides slightly more illumination than a 100-w light bulb and burns for 9 hr on one fuel cylinder. (Otto Bernz Co., Inc., Dept. SM, 280 Lyell Ave., Rochester, N.Y.)

Fire Extinguisher

Chlorobromomethane is the extinguishant in a new hand fire extinguisher that measures 7.5 in. in length and 1.5 in. in diameter. The extinguishant, which is packed in an 8-oz cartridge, is effective against oil, gasoline, grease, electric, paint, and chemical fires. It is released by a finger-operated valve and atomized by carbon dioxide under a pressure of 150 lb/in.^{2} (E. Machlett & Son., Dept. SM, 220 E. 23 St., New York 10.)

Color Film

Anscochrome is a new high-speed reversible color film with a daylight exposure index of 32. It is available in daylight type for 35-mm magazines and bulk loads, and in sizes 120, 620, and 828. It is reported that the new film maintains color balance even with over- or underexposure and that it requires 25 percent less processing time in the first developer solution. (Ansco News Bureau, Dept. SM, 175 Clinton St., Binghamton, N.Y.)

Vapor-Pressure-Actuated Thermometer Systems

Vapor-pressure-actuated thermometer systems that record on uniform charts are now available. A "varying-ratio" linkage converts the nonlinear vapor pressure-temperature curve into a linear deflection of the recording pen. The linkage is available for all ranges from −20 to 600°F. (Bristol Co., Dept. SM, Waterbury 20, Conn.)

Viscosimeter

An industrial model of the Hoeppler viscosimeter is furnished with six calibrated balls, two made of heat-resistant glass, two of corrosion-resistant steel alloy, and two of chromium steel. Accuracy is ± 1 percent over a range from 0.2 to more than 100,000 centipoises. Three interchangeable thermometers provide temperature ranges of −35° to +10°, 0° to 55°, and 50° to 100°C. The constant temperature of the water is maintained by a 100- to 220-v electric heating unit and a pneumatic stirring device. (Fish-Schurman Corp., Dept. SM, 70 Portman Rd., New Rochelle, N.Y.)

Quick-Connect Plugs

New miniature quick-connect plugs for coaxial circuitry are available in 50-, 70-, and 93-ohm types. Mating is accomplished by pushing the units together over a spring-loaded lock that maintains the connection at constant pressure. The connectors, which are made of Teflonx dielectric, are silver-plated; pins are gold-plated. The 50-ohm type is 0.73 in. long and weighs 0.08 oz. Insulation resistance is 100,000 Mohm, capacitance 2 μμf, rating 600 v. (Microdot, Dept. SM, 1826 Fremont Ave., South Pasadena, Calif.)

Speed Reducers

New prefabricated, miniature speed reducers with servo-mount ends are available in 448 different speed ratios from 1:1 to 531,441:1. Other special ratios may be obtained upon request. The units, which are rated at 1/40 hp, have hardened, hobbed spur gears and may be mounted either by means of four tapped mounting holes or by means of a clamp assembly. (Metron Instrument Co., Dept. SM, 432 Lincoln St., Denver 3, Colo.)

Transparent Typewriter Bail

The Marken transparent typewriter bail is manufactured in 30 models. Each model is available with electrochemically etched markings for pica or elite type; the scale reads to left and right from zero in the center; bails are furnished with two or three rollers. Marken bails are not adaptable to any typewriter on which the metal bail is riveted to the arms or on which the bail and arms are made in one piece. (J. J. Kennedy Corp., Dept. SM, 20 Henry St., Byram, Conn.)

Spray-on Cement

Rubber-resin cement suitable for a variety of uses—for example, sealing packages—has been packed in an aerosol spray container that holds 11 oz of cement. The adhesive is waterproof and resistant to soap-and-water cleansing, but it is dissolved by dry-cleaning solutions. (Walsh Adhesive Corp., Dept. SM, 2024 Peel St., Montreal, Quebec, Canada)

——Saunders Books

Romer - The Vertebrate Body

Here is a comparative study of the vertebrate body, including, but not overemphasizing the human structure. Form and function are clearly detailed and illustrated with a wealth of drawings. Paleontological background, histological material and embryology are woven into the text.

By Alfred Sherwood Romer, Alexander Agassiz Professor of Zoology and Director, Museum of Comparative Zoology, Harvard University. 644 pages, 6″ x 9″, with 390 figures. $7.00. *Second Edition!*

Turner - General Endocrinology

New (2nd) Edition—Thoroughly revised, this book treats endocrinology as a basic biologic science and presents the anatomical, physiological, embryological and clinical aspects in both plants and animals. New chapters are: Adaptive Reactions to Stress and Endocrine-Like Mechanisms.

By C. Donnell Turner, Ph.D., Lecturer in Biology, Tokyo Army Education Center, Tokyo, Japan. 553 pages, 6″ x 9″, with 71 figures. $8.00. *New (2nd) Edition!*

Willier, Weiss and Hamburger - Analysis of Development

The various stages in the embryonic development of animal organisms are masterfully covered, summarizing the present knowledge and the problems under investigation. Every chapter was written by a specialist in the field.

Edited by Benjamin H. Willier, Professor of Zoology, Johns Hopkins University, Baltimore, Maryland; Paul A. Weiss, Member, Rockefeller Institute for Medical Research, New York; and Viktor Hamburger, Professor of Zoology, Washington University, St. Louis, Missouri. 735 pages, 7″ x 10″, with 248 illustrations. $15.00.

Villee - Biology

This sound basic text for the beginning course, now in its *Second Edition,* is extremely well known and widely used. It presents the fundamentals of biology with adequate treatment of both plant and animal life, and more than usual attention to the human organism. The author's style is a model of good textbook writing. There are 293 well chosen illustrations.

By Claude A. Villee, Harvard University. 670 pages, 6″ x 9″, with 293 illustrations. $6.50 *Second Edition!*

W. B. SAUNDERS COMPANY West Washington Square Philadelphia 5

Science and Technology

(From the month's news releases; publication here does not constitute endorsement.)

Micropipettes

Research Specialties is offering a new line of Pyrex micropipettes in several different types. The volumetric-transfer type is available in 43 different capacities ranging from 1 μl to 1 ml. Other available types include the following: blood transfer, self-filling transfer, self-adjusting transfer, graduated measuring, Lang-Levy, and dilution. Uncalibrated blanks of several of these types are also available. (Research Specialties Co., Dept. SM, 1148 Walnut St., Berkeley, Calif.)

Cord-End Circuit Protector

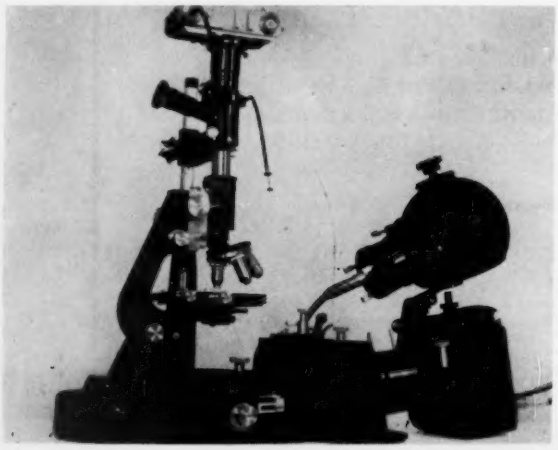
A circuit breaker has been designed for installation on the cord end of household electric appliances. The breaker will protect circuits carrying 3 to 10 amp. Service can be restored within 10 sec by means of a reset button, but the breaker will not maintain a circuit that has not been cleared. (Mechanical Products, Inc., Dept. SM, Jackson, Mich.)

Eradicable-Ink Typewriter Ribbon

Del-e-tape, a typewriter ribbon that is inked with eradicable ink, has been placed on the market. Del-e-tape Deleter, a liquid ink eradicator, is used for erasing. (Aetna Products Co., Dept. SM, Hicksville, N.Y.)

Fluorescence Analyzer

Fluorex fluorescent equipment can be used for either micro- or macrofluorescence analysis. The instrument is equipped with two interchangeable mercury-vapor burners, one a maximum-pressure burner for weakly fluorescent materials and high magnifications, the other a high-pressure burner for highly fluorescent materials and medium-to-low magnifications. The unit, which can be used with a microscope of any make, is also equipped with a microcamera for black-and-white and color photography. (William J. Hacker and Co., Inc., Dept. SM, 82 Beaver St., New York 5.)



Parliamentary Rules at a Glance

Pan-L-View is a new slide rule that presents the generally recognized answers to eight basic questions about each of 36 types of parliamentary motions. The answers are obtained by aligning a pointer on the slide with another pointer that corresponds to one of the 36 motions. Concise definitions of the types of motions, as well as their order of preference, are presented on the right-hand side of the device. The rules are based on *Robert's Rules of Order Revised* and they are in conformity with the principles of parliamentary procedure stated by O'Brien's *Parliamentary Law for the Layman* and Sturgis' *Standard Code of Parliamentary Procedure.* (Pan-L-View, Dept. SM, Room 235, 708 Church St., Evanston, Ill.)

Metal Lacquer

Packaged in aerosol cans, Delkote metal lacquer can be applied quickly to bright metal hardware. It dries in 10 min and the dried coating provides protection from fingerprints and prevents tarnish. Two coats are recommended for protection of polished metal from the weathering effects of outdoor exposure. (Delcote, Inc., Dept. SM, 1419 Faulk Rd., Wilmington, Del.)

Drafting Aid

Two types of drafting aids have been made from Bakelite rigid vinyl sheet. One type, which is available in various sizes, is essentially a straightedge attached to a quadrant with a retractable pivot at its center. The other is a circular instrument designed to simplify the construction of geometric figures. (Graphic Calculator Co., Dept. SM, 633 Plymouth Court, Chicago 5, Ill.)

Dielectric Test Instruments

Both visual and audio indication of leakage, breakdown, and short circuits are available in a new series of dielectric test instruments with output voltages up to 6 kv. The detector circuit has sufficient power to actuate external circuit elements, and output voltage is continuously variable. The instruments weigh 20 lb and fit in a steel case that measures 9¾ by 9½ by 12½ in. (Associated Research, Inc., Dept. SM, 3758 W. Belmont Ave., Chicago 18, Ill.)

Reusable "Ice"

Three pounds of a reusable, nonmelting "ice" have the same cooling capacity as 15 lb of ordinary ice. The cooling agents are sealed in Krene plastic bags of various sizes from "picnic" to "sportsman's." After use, the plastic bags can be refrozen in a refrigerator and used again. The manufacturer reports that the cooling agents are harmless. ("Bud" Wilson, Inc., Dept. SM, 232 S. Beverly Dr., Beverly Hills, Calif.)

designed for the professional...

LEITZ ***LABOLUX*** MICROSCOPE

Scientists, physicians and technicians who must work for long periods with a microscope will appreciate the new Leitz LABOLUX with its *fatigue-free operation, precision optics* and *unexcelled dependability.*

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Science and Technology

(From the month's news releases; publication here does not constitute endorsement.)

Directional Scintillation Counter

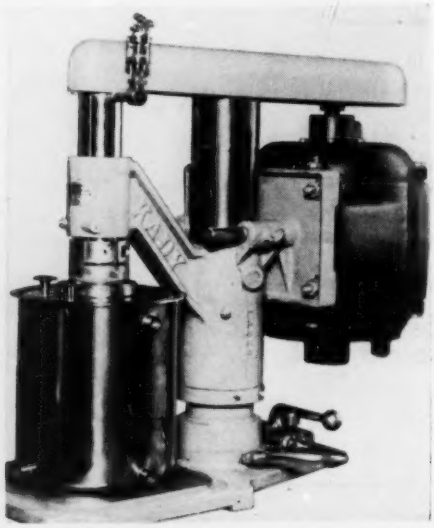
Heavily shielded for maximum directionality, a new collimated scintillation counter is supplied with a 1- by 1-in. sodium iodide crystal. When the removable forward shield is in place, a ratio of at least 50 to 1 is obtained between count rates from an I^{131} source within the acceptance cone and one outside the cone at the same distance from the crystal. The angle of sensitivity may be varied by changing the threaded lead collimator in the nose of the shield. The new counter includes a photomultiplier that has been chosen for good signal-to-noise characteristics. It is supplied with cable for connection to any scaler or rate meter. (NRD Instrument Co., Dept. SM, 6429 Etzel Ave., St. Louis 14, Mo.)

Sawhorse Brackets

"Speed Clamp" brackets are intended for use in the construction of sawhorses, tables, benches, scaffolding, and other supports, particularly when it is desirable that the support can be knocked down for storage or when the support is needed only temporarily. The brackets fit 2- by 4-in. lumber. (Chesney, Inc., Dept. SM, 720 Towne Ave., Los Angeles, Calif.)

Dispersion Mill

A laboratory model of the Kady industrial dispersion mill has been made available. The capacity of the new model is 1/3 to ½ gal, and all working parts are made of stainless steel. The mill occupies 25½ by 15¼ in. of bench space and requires less than 30 in. of head room, including space for the operation of the hydraulic lift. It is driven by a 1-hp, three-phase, 220- or 440-v motor. (Kinetic Dispersion Corp., Dept. SM, 95 Botsford Pl., Buffalo 16, N.Y.)



Automobile Jack

A newly marketed folding bumper jack is of tripod design. The two rear legs have swivel feet, and all three legs are joined together by safety chains. The folding cold-forged steel lifting handle fits the screw-type ball-bearing head of the tripod. (Snyder Manufacturing Co., Dept. SM, Philadelphia 40, Pa.)

Inflatable Pillows

New inflatable pillows made of Krene plastic are available in square, triangular, and circular shapes. Two large wooden buttons are supplied for attachment through a center hole in each pillow after the pillow has been covered with whatever fabric is desired. The square pillow has 15-in. sides, the triangular one 17-in. sides, and the circular one is 15 in. in diameter. (Plastic Innovations, Inc., Dept. SM, 185 Riverdale Ave., Yonkers, N.Y.)

Duo Thermostat

The new Duo Classic thermostat, which has been designed to operate with both air conditioning and heating units, has a single switch that controls all functions, of heating, cooling, and air circulation. It is reported that the thermostat will prevent the selected temperature from varying more than a fraction of a degree and thereby eliminate overheating and underheating. (Marvin Hahn, Inc., Dept. SM, 2889 W. Grand Blvd., Detroit 2, Mich.)

Currency Converter

A new compact guide to foreign exchanges translates the value of the U.S. dollar into 26 foreign currencies. The Dollar-Dialer, made of Bakelite rigid vinyl sheet to fit into wallet, purse, or passport case, indicates the basic monetary unit for each foreign country and its value in dollars, the number of units that can be bought for $1, and the equivalent values in each foreign currency for 16 U.S. monetary figures between 10 ct and $100. The values are listed on a movable disk that is dialed to the desired foreign currency and read through a cutout; reverse calculations can also be made. (I. and M. Ottenheimer, Dept. SM, 23 S. Howard St., Baltimore 1, Md.)

Small-Parts Cabinet

A steel cabinet designed for small-parts storage has eight transparent plastic drawers, each of which measures 5⅞ by 2¾ by 1 7/16 in. The drawers have adjustable crosswise and lengthwise dividers, safety catches, and label slots; the cabinet, which is finished in silver-gray baked enamel, has rubber feet. (General Industrial Co., Dept. SM, 5738 N. Elston Ave., Chicago 30, Ill.

Skyscope

A new reflector-type, 60-power telescope designed for use by amateur astronomers and the general public is on display at planetariums in New York, Chicago, Ill., and Fort Worth, Tex. Possessing the requisite power and clearness of definition to reveal the moon's mountains and craters, Saturn's ring, Jupiter's moons, Mars' planet markings, and some of the nearer double stars, the Skyscope is 3½ in. in diameter; it has an aluminized mirror and an all-metal mounting. (Skyscope Co., Dept. SM, 475 Fifth Ave., New York 17.)

Electronic Color Microscope

Electronic projection in natural color of microscopic images, enlarged as much as 30,000 times, was demonstrated at the annual meeting of the American Medical Association in Atlantic City. The new electronic color microscope developed by the CBS Laboratories has magnifying power sufficient to project images of cancer cells to a diameter of 7½ in., red corpuscles to 5 in. in size, and the typhoid bacillus to ½ in. The system enables microscopic specimens, living or dead, to be enlarged and projected electronically on a 6-ft screen with resultant images many times brighter than those produced by conventional optical methods. It also permits the transmission of such images via the cable and microwave facilities of television to distant points. The new microscope is expected to assist scientists in the study of polarization and dark-field and other phenomena heretofore obscure because of their sensitivity to light. (Columbia Broadcasting System, Inc., Dept. SM, 485 Madison Ave., New York 22.)

Star Projector Unit

A new packaged visual astronomy unit includes a Spitz Junior star projector, a metal-and-canvas projection dome 10 ft in diameter, and a table with telescoping legs to support the projector. A meridian projector, arrow pointer, dome illuminator, and rheostat controls for all accessories are also provided.

The power-driven star projector gives motion equivalent to 1 day in 4 min.; it projects about 300 stars and 50 constellations. It is adjustable for month and latitude and it is provided with an artificial horizon. The dome illuminator can be used to provide sunset and sunrise effects. About 15 min are required to set up or take down the projection dome. The instructions include suggested lectures and procedures. The package is being produced on a limited basis only. (Harmonic Reed Corp., Dept. SM, Rosemont, Pa.)

Folding Reflector

Made of stainless steel, a dual-beam folding reflector has recently been made available for use with the photographic flashguns of Camera Optics Corp. The unit folds to pocket size. When it is open, the reflector can be locked into either of two positions, one that provides concentrated light and one that provides pan light. (Camera Optics Corp., Dept. SM, 101 W. 47 St., New York.)

Flame Photometer

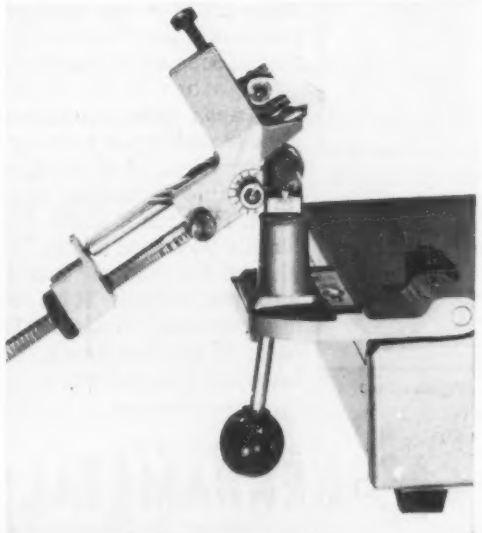
Perkin-Elmer has announced a new flame photometer, model 146, with a stainless steel burner and a simplified atomizer. The unit will operate on natural, city, propane, or acetylene gas. The new atomizer uses a straight-through capillary. There is a ground glass joint between the atomizer and the atomizer chamber. Excess solution in the stream is drained through a fitted glass filter. The funnel has a flow rate of 4 to 6 ml/min. As little as 2 ml of sample is required to obtain a reading. Accuracy of ±2 percent is possible on routine sodium and potassium analysis; accuracy is ±1 percent by internal-standard measurements. Alkaline earths may be analyzed. The dimensions of the metal cabinet are 21⅜ by 13¼ by 18¼ in. The sloping front panel is made of Fiberglas. (Perkin-Elmer Corp., Dept. SM, Norwalk, Conn.)

Miter and Protractor

Compound angles can be cut with the aid of Magnecut miter and protractor. The miter is cast from hard-grade aluminum; all working parts are made of brass. An Alnico magnet at each end of the miter holds the saw at proper tension. Two-way angle adjustment is provided by two 45° protractors, one in the horizontal plane and the other in the vertical plane. The unit weighs less than 1 lb. (Dresden Mfg. Co., Dept. SM, 2375 Walnut Ave., Long Beach 6, Calif.)

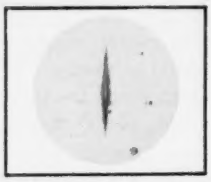
Drill Sharpening Kit

A new drill sharpening kit has been designed primarily for use with 6-in. bench grinders, but it can be used with other grinders if either the grinder or rocker plate is blocked up. The kit consists of a drill-grinding attachment that holds the drill in a sliding V-block (for ⅛- to ¾-in. twist drills) rocker plate, a metal base 12 by 10¾ by 3 in., a 3-way drill-point gage 4 in. long, and an instruction manual. (Swanson Mfg. Co., Dept. SM, 1236 Sherman Ave., Evanston, Ill.)



A composition that is almost twice as hard as the hardest steel ...that's KENNAMETAL*

Kennametal is the registered trademark of a series of hard alloys of tungsten, tungsten-titanium, and tantalum carbides... the *hardest* practicable metals made by man. In scratch hardness tests, these hard carbide particles are between sapphire and diamond. On the Rockwell "A" Scale, different Kennametal grades test from 90.0 to 93.0, while HSS 18-4-2 heat-treated steel tests a maximum of 85.0. The Knoop Test gives 2100 (K100) for Kennametal and 800 (K100) for steel.

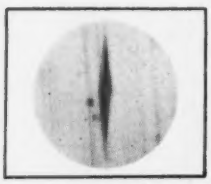


K8 tungsten carbide

18-4-2 steel

Photomicrographs above show results of Knoop hardness test on Kennametal K8 and HSS 18-4-2 steel at 100g. Impression in the Kennametal is only about half of that on the steel.

Titanium carbide



Tungsten carbide

Photomicrographs at left are of Knoop tests on grains of carbide ingredient of Kennametal. Knoop test numbers (at 100g) are: Tungsten carbide, 1900; tungsten-titanium carbide, 2200; titanium carbide, 2500. These tests show those carbides are from two to three times as hard as steel in the absolute scale of Kgs per square mm of area of impression.

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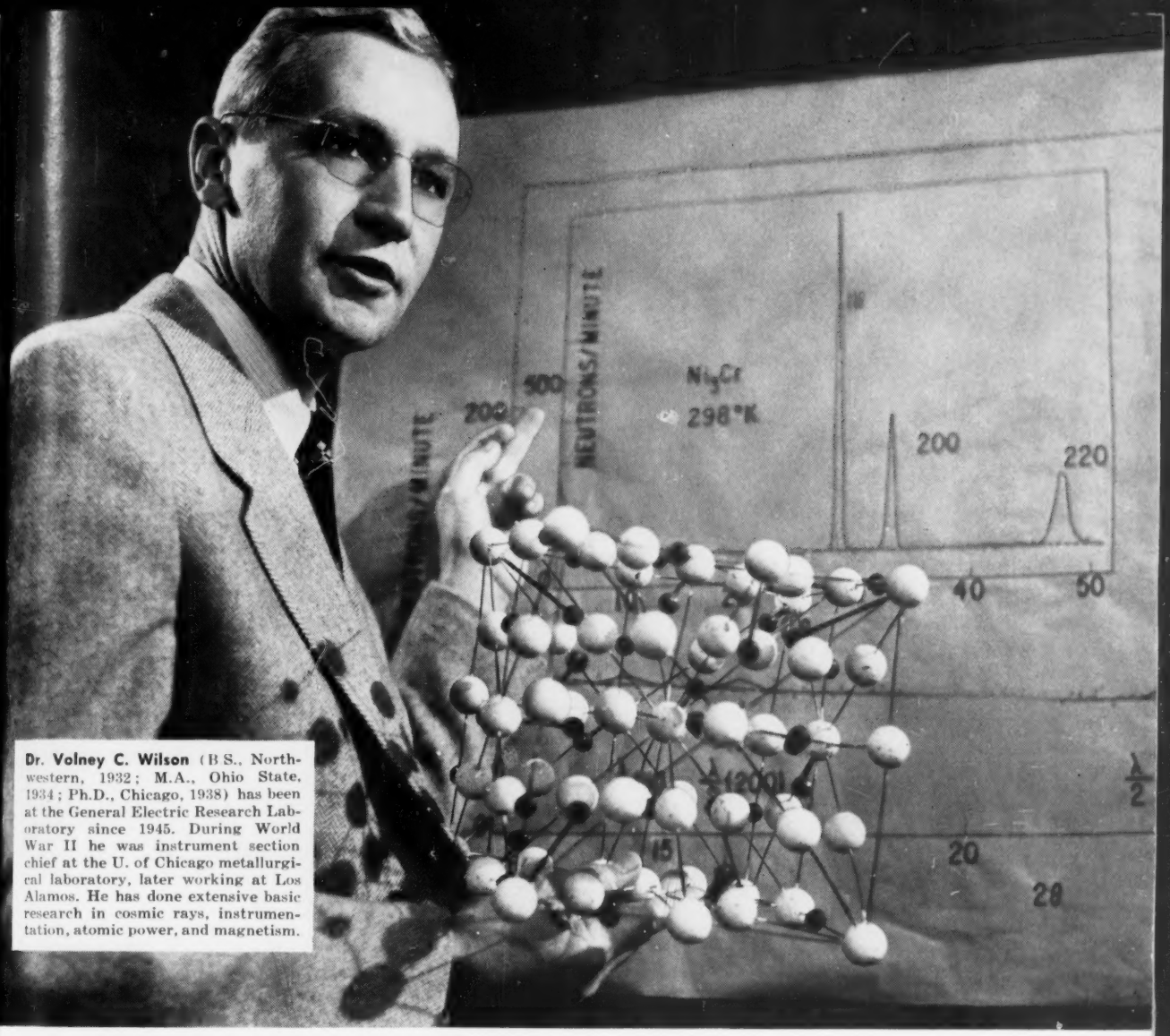

Dr. **Volney C. Wilson** (B.S., Northwestern, 1932; M.A., Ohio State, 1934; Ph.D., Chicago, 1938) has been at the General Electric Research Laboratory since 1945. During World War II he was instrument section chief at the U. of Chicago metallurgical laboratory, later working at Los Alamos. He has done extensive basic research in cosmic rays, instrumentation, atomic power, and magnetism.

Why magnets are magnets

General Electric's Dr. Volney C. Wilson uses neutrons to discover fundamental facts for improving magnetic materials

While Volney C. Wilson was director of instrumentation and control for the first atomic pile, under the University of Chicago stadium, Enrico Fermi demonstrated to him and others working on the project that neutrons could be diffracted in the same manner as x-rays. Several years later, when Wilson's interests turned to an intensive study of magnetism, he recognized the special value neutrons would have in revealing atomic arrangements in magnetic materials. Neutrons are not affected by *electric fields*, but—since they are very much like little magnets themselves—they are scattered by *magnetic fields* within crystals.

Accordingly, Dr. Wilson designed and constructed a unique *neutron diffraction spectrometer* at the General Electric Research Laboratory. It is now in operation at Brookhaven National Laboratory, giving G-E scientists new insight into the problem of why magnets are magnets. Wilson believes that learning new fundamental facts about "atomic-magnetic" structure will result in better magnetic materials—and that even a small improvement in these materials will significantly increase their usefulness in computers, control equipment, and color television.

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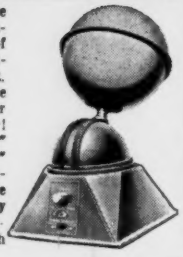

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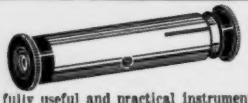

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